Annual Subscription Price, $3. 82 *Published Ten Times a Year.*

The works of the Lord are great, sought out of all them that have pleasure therein.—Ps. cxi, 2.

THE SIDEREAL MESSENGER.

FEBRUARY, 1890.

CONTENTS.

WM. W. PAYNE, EDITOR,

DIRECTOR OF CARLETON COLLEGE OBSERVATORY.

NORTHFIELD, MINN.

Entered at the Post Office at Northfield, Minn., for transmission through the mail at second class rates.

MARIA MITCHELL.

THE SIDEREAL MESSENGER.

CONDUCTED BY WM. W. PAYNE.

DIRECTOR OF CARLETON COLLEGE OBSERVATORY, NORTHFIELD, MINN.

VOL. 9, NO. 2. FEBRUARY, 1890. WHOLE NO. 82

MARIA MITCHELL.

MARY W. WHITNEY.*

For THE MESSENGER.

Maria Mitchell was born on the island of Nantucket Aug. 1, 1818. Her father and mother were both Quakers, and her mother was descended from the earliest settlers of the island. Her father had a natural taste for scientific study, and throughout his active life, first as teacher and afterwards as bank cashier, he devoted his leisure time to astronomical pursuits. He was for many years employed by the United States Coast Survey in observations pertaining to the survey of the island. In these observations his daughter began to assist him at the early age of eleven. Her education was the best Nantucket could afford, of a thoroughly substantial but simple character. It gave her only the rudiments of the science, and the mathematics which her later studies required. When eighteen years old she became librarian of the Athenæum library, an excellent library well supplied with scientific books, and attesting the intellectual character of the Quaker town. In the reading room of this library Miss Mitchell, by her private reading, laid the foundations of her mathematical knowledge. Throughout these years she continued her father's assistant, and gradually passed to independent observations. She swept for comets on the roof of the Pacific bank, still heading the main street of Nantucket. She found several before their discovery was known to her, and in the mean time was training herself by her study for the investigation of the positions she obtained. She computed several orbits from her own observations. But not until 1847 did she sweep her glass over that particular comet which brought her to the notice of the public.

* Director of the Observatory, Vassar College, Poughkeepsie, N. Y.

Of this she was original discoverer. A more extended knowledge of this discovery was doubtless brought about through the conferring of the Danish medal. Some years previous to this the King of Denmark had offered medals for the discovery of comets, his object being to incite his own subjects to a more zealous pursuit of astronomical investigation. But the medal in this case was sent across the Atlantic to the young woman in Nantucket.

The public interest aroused by this discovery brought to Miss Mitchell wider opportunities. A Clark telescope of five inches aperture, well equipped and mounted, was presented to her. She was appointed computer for the American Ephemeris and Nautical Almanac, and was on many occasions employed by the Coast Survey for astronomical work. She traveled abroad and met the leading astronomers of England and the continent. Sir John Herschel and Sir George Airy became her friends and maintained correspondence with her. She traveled in Europe a second time several years later, and during this tour made a visit to the famous Russian Observatory at Pulkowa. Her interest in cometary work, both practical and theoretical, continued, and after she came into possession of a well-mounted instrument she took up also the study of double-stars.

In 1865 Miss Mitchell was appointed professor of Astronomy at Vassar College. This college for young women, the pioneer college in the East, was opened to the public in the fall of that year. Miss Mitchell had not sought this appointment; she did not regard herself as especially well fitted to teach nor as possessing those gifts which fit one for professional work. Nevertheless this unsought position offered many inducements, and Miss Mitchell had naturally become much interested in the extension of the educational opportunities of young women. Therefore she decided to enter the new field. As her principal duties hereafter were those pertaining to the class room, her instrumental work was necessarily curtailed, but her interest remained unabated and she devoted all the time at her command to the telescopes. Her first investigations were, of course, those pertaining to the latitude and longitude of the new Vassar Observatory. This Observatory had good glasses, but the mounting of both transit and equatorial offered much to be

desired. And one of the good things accomplished by Miss Mitchell during her professorship at Vassar was the improvement of the equatorial both in its glass, which was recut by Clark, and in its mounting. The final value of latitude adopted was secured by observations with a zenith telescope supplied by the U. S. Coast Survey. The final longitude determination was made by electric connection with Cambridge. Miss. Mitchell's observations with the equatorial were now mainly directed to Jupiter and Saturn. Several of her papers were published in Silliman's Journal. When photography became valuable in its application to the study of the solar surface, Miss Mitchell constructed at her own expense the necessary apparatus for photographing the sun, and trained her students to take these photographs. Miss Mitchell was associated with the expedition to Burlington, Iowa, made under the direction of Professor Coffin, Superintendent of the Nautical Almanac, for the purpose of observing the total solar eclipse of August 7th, 1869. Her report of this eclipse is contained in Professor Coffin's general report, published several years later. Again in 1878 she formed a party of her own for observing the solar eclipse of that year. Her station was then at Denver.

Miss Mitchell held the chair at Vassar until close upon her seventieth year. She then resigned, feeling the encroachment of years, and retired to Lynn, Mass., where she had been living at the time of her summons to Vassar. She planned to mount again her five-inch telescope and resume in a leisurely way her work upon double-stars. But health and strength steadily failed. She died on June 28th, 1889.

Professor Mitchell's influence as a teacher was of the highest order. It was helpful and stimulative. Vassar College has owed much to her. Her extended reputation added to its early success, and her force of character was a bulwork of strength in its initial days, when its object met but a partial public sympathy and its position was still insecure.

A VISIT TO SLOUGH.

D. W. EDGECOMB.

For The Messenger.

The yearly visitors to Windsor Castle may probably be numbered by hundreds of thousands. Those who go by the Great Western railway leave the main road at Slough, and cross the Thames upon a curved line of rails, which reveal as you approach, the long walls and lofty towers of the Castle.

A few travelers, animated by different feelings from those of the great majority, turn in the opposite direction and seek the quiet churchyard of Stoke Poges, where, amid the many mouldering heaps that lie in that peaceful spot, they may sit beside the grave of the poet Gray, beneath the yew tree's shade. But it is rare that a traveler stops at Slough itself, and reveals to those about the station the bent of his mind or his occupation, by inquiring the way to the Herschel house, or the place where the great telescope once stood.

There is probably no spot in the world more interesting to astronomers of every grade, whether professional or the youngest amateur, the makers or the users of telescopes, than the house and garden which are associated with the life, labors and discoveries of Sir William Herschel. It is difficult to express the gratification one feels whose admiration of Herschel has been growing almost from his school boy days, and who finally finds himself standing before the modest house where he lived. It stands close to the street, in a pleasant part of the town, a few minute's drive from the station, and would seem to afford, even now, all the quiet and seclusion an astronomer could desire.

It has the name "Observatory House" upon the gate-post in accordance with a very pretty custom among the English people of giving names to their houses especially in the smaller towns, and the suburbs of the larger ones. Every one will be pleased to know that after having been in the possession of others for many years, the house is now again occupied by members of the family, the children of Sir John Herschel; and the pleasure of a visit is greatly enhanced by their kind and hospitable reception and their evident enjoyment of the interest manifested by the visitor.

Upon making known our errand, we are asked to enter the house, and find ourselves in a little reception room, or hall. Here our attention is at once attracted by a fine specimen of the Herschel six-inch telescope, the size most used by himself, and of which he made so many for others. It is of mahogany, very neatly finished, with octagonal tube, and the rather cumbersome framed stand with which, I believe, all the telescopes of this size were furnished. The instrument, with the exception of the mirror, was probably the work of his brother Alexander. The polish of the mirror is still good, and the flat and eye-piece holder are in perfect working order. The adjustment for focus in this instrument is made by sliding a brass plate, which carries the flat-arm and eye-tube up and down the main tube between guide pieces, so that both flat and eye-piece move together towards or away from the great mirror.

One can hardly resist the wish to try its performance upon some of Herschel's own objects,—Castor, or α Herculis, or η Coronæ, or the Debilisima. These latter Herschel could not see with his six-inch mirrors, but one can hardly doubt that now they would be revealed by one of them. And then the question would be, have the stars grown brighter, or have the eyes of modern observers, by some kind of evolution, and under the spur of practice, competition, or desire, grown more sensitive?

After a loving inspection of this instrument, our host asks us to turn, and there, on the other side of the room, partly concealed by flowers and a bunch of bracken from the "Burnham Beeches," to which he has lately made an excursion, shines the broad face of the speculum of the "forty-foot" telescope. We should know it anywhere. We knew that it was sealed up within the tube by Sir John Herschel, upon the merry occasion in 1839, when the tube was lowered to the ground and placed horizontally across the circle occupied by the mounting; and that, before the mirror was finally replaced, a long table was arranged within, at which all the little ones feasted; and then, each provided with a hammer, they "made the old telescope rattle and ring," all as described in Newcomb's "Popular Astronomy." But we now learned that some years afterwards a great tree fell across and broke the tube, but fortunately without injuring

the speculum. Some ten or twelve feet of the tube was then cut off and taken to one side of the garden, and carefully placed upon a portion of the original supports, while the mirror was brought into the house and securely suspended by an iron ring or strap, within the recess in the wall of the reception room where we then saw it. Our host was one of the "little ones" who feasted in the great tube with the happy party of 1839, and remembers well the racket made by their hammers, no small share of which he claims to have contributed.

And there is the great mirror, with its three-quarters of a ton of metal. Its surface is bright, but plainly not from the original polish. A network of fine scratches plainly shows that hands far from having any claim to optical skill have been at work. But a practiced eye may readily determine what its original surface was. It had undoubtedly a high and brilliant luster. Here and there a short scratch, with edges rounded by subsequent polishing, reveal the accidental work of stray bits of emery while under the hands of its maker, and suggest to the mind the vexation with which he viewed them after perhaps long hours of work, which he hoped would leave him a perfect surface. But there were only a few of these, while the great casting was a most excellent one with scarcely a pit or blemish in its whole area. Only those who have cast, ground, and polished mirrors of speculum metal, even of small dimensions, can fully appreciate the herculean nature of the task thus accomplished.

Probably a somewhat imperfect figure prevented the performance that its great size gave hope of, and explains the meagre reports of the appearance of objects seen by it, except where light alone was required. For even inside the marginal inch, not measured in the well known statement of its dimensions, a practiced eye, again, may plainly see that the edge is flattened or rounded, denoting over correction, and good definition could probably only be obtained by the use of a rather broad diaphram.

But the garden now remains to be visited, and with unabated interest, we pass to the rear of the house and step out upon the historic ground. A quadrangle presents itself measuring perhaps seventy-five by two hundred feet, surrounded by a neatly trimmed hedge, and covered with

smooth grassy sod, of that lovely rich green which, even in November, delights the eye of the American visitor to England. Smooth, except that nearly in the center is a square block of cut stone, upon which rests a disc of iron, the grinder for the great mirror. About this a ring of gently heaped earth indicates the foundation of the circular bed upon which the mounting revolved, with its spars and braces, its cross-bars, platforms and hoisting tackle.

It is just a hundred years since the great telescope was completed as signaled by the discovery of Enceladus. An upper story has been added to the house, but its lower part with the garden and its surroundings have scarcely changed. As we stand within the grass grown circle, the remark of the French astronomer comes vividly to mind: "There is no spot in the world where so many astronomical discoveries have been made as in that little garden at Slough."

It is a pleasant room in the house, the windows of which look out upon the garden; and at one of these the gentle sister of our guide and host appears, enjoying the pleased interest with which we examined the place and all that it contains; and it is not at all difficult to trace in her features a resemblance to her illustrious aunt, the loving companion of the labors of him who made the place historic.

Far above the roof of the house must have towered the mass of timber and the black tube suspended in the midst of it. The creaking of blocks, and the heavy rumble of the wheels upon the rails of the great circle, as the instrument was slowly raised, lowered or swung in azimuth, must have been a familiar nightly sound here a hundred years ago.

The speculum end of the tube, neatly painted and well-preserved, stands at one side. It is a substantial piece of iron work, well fitted to sustain the weight of the speculum, and if the whole instrtment was of similar workmanship, there were weight and strength sufficient.

At one corner of the garden stands the little house used by Sir William and his sister as the manuscript or computing house. It is unchanged, and one goes almost reverently into the principal room, the windows of which also look out upon the garden, and from which the telescope was in full view. Here in the quiet hours the patient sister sat, writing as the words of her brother came to her ears describing now

a nebula or a cluster, now the colors of a double-star, or perhaps giving the number of a count of a field of stars; intermingled, we cannot doubt, with expressions of astonishment, wonder, or delight, at the magnificent scenes that continually presented themselves to his sight. Perhaps it is an August night, and portions of the Milky Way in Cygnus or Sagitarius are sweeping across the field; or it may be in the frosty air of a winter evening, as the glories of Orion or Gemini stream upon his vision, flashed from the upturned face of the great speculum.

In a rear room of the computing house are tools used by Sir William, Alexander, and Sir John Herschel, and in an upper room is preserved a part of the polishing apparatus for the four-foot speculum. It is the segment and arm for grasping and rotating the polisher, as figured in Sir John Herschel's book on the "Telescope."

Here, as he worked, the astronomer grew old, and saw the long night approach in which there is no observing. With what regret must he have felt the slow increasing weight of years, and, with the consciousness of so much yet remaining to be seen, how sadly as he climbed into the little observing house at the mouth of the great tube, must he have thought, that soon he would turn his eye from the eye-piece and his hand from the adjusting screw for the last time.

Here, as a child Sir John Herschel played and climbed about the mechanism of the great telescope, and here he began the labors which so fitly supplemented those of his father. Here he prepared the mirrors with which his observations at the Cape of Good Hope were made. After his return he settled in Kent, but the Slough estate was retained, and four children, two sons and two daughters, have now made it their permanent home. Astronomers may be assured of a cordial and kindly welcome. Two were at home on the day of our visit, Colonel A. S. Herschel, and a sister; both were born at the Cape of Good Hope, and their earliest recollections are associated with the astronomical work of their father. The eighteen-inch mirrors used for the Cape observations are in possession of one of the sons, and are closely sealed for preservation.

As we left the house the wind from the south brought

to our ears the faint notes of a bugle from the walls of Windsor Castle. One can but feel grateful to one occupant of that royal keep, the monarch who could find time, even while devising plans for uncivilized warfare upon his rebellious subjects in America, or for thwarting the wishes and interests of the people of London, to honor himself and his reign by the aid given to the humble musician of Hanover, compared with whom Pitt and Burke and Fox and "all the king's counsellors" sink into insignificance. One can imagine the vexation with which Herschel might receive, on some clear night when he hoped for a period of uninterrupted observation, a gang of cavaliers from the Castle, who thought they must imitate the king by patronizing the great telescope and its maker.

Nor could we forbear the comparison between the enjoyment our visit had afforded, and that of the police-conducted assemblage that is permitted hourly to gaze upon the royal trappings of the state apartments of Windsor.

LONDON, Dec. 15, 1889.

LETTER FROM THE SUPERINTENDENT OF THE NAVAL OBSERVATORY.

I have the honor to acknowledge the receipt of your letter of the 6th instant, in which you quote from a communication from "the Director of one of our prominent Observatories" the following: "The Superintendent of the Naval Observatory takes the position that he is bound to furnish time signals from the U. S. Naval Observatory to the Western Union Telegraph Company. If the Company uses these time signals to crush out private Observatories it is something which the superintendent cannot help, and for which he is not responsible."

As Professor Pritchett is the only Director of an Observatory with whom I have ever had any correspondence or held any conversation on this matter, there can be no doubt that your information comes directly or indirectly from him. In either case I feel justified in sending you the entire correspondence between him and myself (inclosures marked A, B, and C), for it shows precisely what I wrote, and from it as a whole just conclusions can be drawn.

Any fair-minded man will conclude from my letter of Aug. 27, 1889, that after reading the circulars issued by the Western Union Company, I declared that I could not, on the evidence presented, dispute a right which had been acquired long before my connection with the Naval Observatory. My letter invites the production of proofs to substantiate assertions made by Professor Pritchett, of which those circulars gave no evidence, and declares a purpose to make proper use of such proofs. It goes further; it leaves entirely to the will of Professor Pritchett whether or not his communication shall be made the basis upon which I could institute an investigation of the matter. What more could any one have done under the circumstances? From Professor Pritchett's reply it is manifest that he was satisfied, for the time being, at least, with the terms of my letter, and did not desire to press the matter of the Western Union Company's interference with his business.

This is the only instance to which my attention has been officially called of the aggressions of the Western Union Telegraph Company upon any Observatory; and the correspondence in this case speaks for itself.

While the significance of the clause in my letter, "The right of the Western Union Company to so use our daily signal I cannot dispute; it rests upon an arrangement in existence long before I came to the Observatory," was fully understood by Professor Pritchett, who is quite familiar with the steps that have led to the existing arrangement, it may not be so to others. I shall therefore refer as briefly as possible to the history of this arrangement. From the disconnected correspondence on the subject at hand and from information given by officers who were connected with the Observatory when the arrangement was entered into, I gather the following:

The Western Union Telegraph Company has been receiving Observatory time since about 1863. In December, 1876, the Superintendent of the Observatory formally proposed to the Vice-President of the Western Union Company that time should be sent to a prominent jeweler in Leavenworth who had made written application to him for it, and also for the use and convenience of large cities. It was not until after considerable delay, and importunity on the part of Observa-

tory officials, that the Western Union Company consented to the arrangement. The time service then had little or no commercial value, and it is doubtful whether the Company was remunerated for its trouble and expense, certainly not to any great extent when it is considered that exchange longitude signals (including the service and time of Western Union officials), signals to time-ball station and other public points were sent without charge. On this point, however, I have no definite information and only suggest a probability.

Under these conditions it can be easily understood that I was not willing to ask the Navy Department (for I have not the authority to do so myself) to discontinue a long established practice without some kind of investigation into alledged abuses of it, and this investigation was not desired by one of the most largely interested persons whose rights, it is claimed, are threatened.

The correspondence between Professor Pritchett and myself shows—

1st. That I was willing upon definite evidence to act in the matter complained of.

2d. That I was willing to accept the letter of Professor Pritchett as a sufficient basis upon which to open an investigation.

3d. That Professor Pritchett was unwilling to assume the responsibility for the charges he made.

4th. That Professor Pritchett (perhaps not directly but by inference), asked *me* to assume a responsibility that *he himself* wished to evade.

5th. That the only complaint that has ever reached me in proper form was dropped at the request of the complainant.

The attitude which this Observatory has assumed towards the Western Union Company as transmitters of time is clearly shown in a letter to Messrs. John Bliss & Co. I inclose a copy of it marked D. It was written in reply to an application from Messrs. Bliss & Co. for a table of corrections during a long interval of bad weather. It emphatically points out that this Observatory does not recognize any relation with the Western Union Company's business, and that it declines to furnish information concerning signals transmitted by that company. So much for your letter.

I now come to an article published in the December number of THE SIDEREAL MESSENGER, headed "Observatory Local Patronage Threatened."

In it it is stated that "the general officers of this commer-"cial company (which we will now name as the Western Union Telegraph Company) interviewed the Superintendent of the U. S. Naval Observatory, and sought and obtained of that officer, as they say, certain definite contract relations by which the telegraph company should have the privilege and right to use the time of the U. S. Naval Observatory for its own uses in commercial sale and barter." By the insertion of the words, "they say," you place the responsibility of this assertion upon the officers of the Western Union Telegraph Company. From whatever source it comes it is absolutely without foundation. The present superintendent of the Naval Observatory (and he is, from the context, the one meant), has never had any correspondence, interview, or communication of any kind with an official of the Western Union Company, on this or any kindred subject, or branch of it, except to call for circulars as mentioned in my letter to Professor Pritchett, the following being the whole of the language used: "Please send me copies of all circulars of the company relating to the distribution of time, in which the Naval Observatory is mentioned or referred to and oblige," etc.

In this connection I beg to return to your letter of Dec. 6, and to invite a comparison of the following paragraph from it with the language of your published article. You write, "While in conversation with a Vice-President of the Western Union Telegraph Company a few days ago, he stated to me that his company was under contract relations with the National Observatory by which they were entitled to use the Washington time throughout the United States for such purposes as they wished in their commercial business." From the following sentence in the published article—"This is no secret on the part of the telegraph company, for the writer has heard a Vice-President of the company very freely speak of the matter"—it is fair to presume that the conversation with the official alluded to in your letter is the source of information upon which your article is based. Now according to your letter the Western Union official said that a

contract relation exists between this Observatory and his company and nothing more. While the old arrangement by which the Western Union Company receives our time signal cannot be called a contract, it is the only agreement with the Observatory that exists, and in the absence of any proof that the Western Union official is not honest and truthful, it is reasonable to assume that he alluded to it. If he did, you have not fairly quoted him, but have put upon his language an interpretation which is stretched far beyond the limits of truth. This is an issue between yourself and the Western Union official.

The article further states—"Whatever arrangements the Superintendent of the United States Naval Observatory entered into with the telegraph company named, by which it was deemed wise to permit this kind of an attack to be made on the local financial support of the Observatories of the country, is not apparently very easy to find out." It also speaks of "this rather extraordinary transaction between a government official and a private telegraph company by which the rights and interests of educational institutions of the land are put in hardship with the prospect of financial loss, to increase the business of a private telegraph company," etc. For these two paragraphs you seem to assume the responsibility.

As any arrangement of a public and official nature could very easily be found out, it must be inferred that you intend to imply that some private arrangement has been entered into between myself and the Western Union Company.

This implication and the inferences to be drawn from it, as well as from the last above quotation from your article, are absolutely false. I have no connection of any kind with, nor interest in, the Western Union or any other time company; nor have I had such connection or interest.

In conclusion I must say that this positive denial of the unwarranted and unjust reflections upon me will be my last communication upon the subject. The controversy which has inspired your uncalled for attack upon me is a purely business fight between persons or corporations engaged in transmitting time for a money consideration, with which I have nothing to do; and although all my sympathies are with the Observatories whose revenue from time service is

devoted to Observatory purposes, I cannot be drawn into the conflict. The efforts which I have made (and successfully in most cases) to use this Observatory in forwarding the interests of other Observatories with which I have had relations will, I believe, be a sufficient defense against any further attempts on the part of your paper to create the impression that I am inimical to sister institutions.

You are at liberty to make this letter public, *with this positive restriction*, that no part of it shall be published unless every word, including inclosures, is embraced in the same article. Indeed it is my wish that you do so, and such a course seems the only fair one open to you. The position in which your article places me before your readers (among whom I have many friends) is sufficient excuse for the plain terms I have used.

A.

St. Louis, Aug. 8, 1889.

Captain R. L. Phythian, U. S. N.,
Supt. U. S. N. Observatory, Washington, D. C.:

Dear Sir: I beg to ask your kindly offices in the following matter.

The Western Union Company has recently served notice upon all railroads using our time that they would be expected to take time signals hereafter from Washington through the Western Union Company. In this notice the company assumes to control the government time service, for which it alone contracts, and alludes to the service maintained by the other Observatories as "rival service." The company also attempts under its contracts with the railroads to prevent us from running our wires into the offices of such roads as desire to retain the present arrangement.

The Western Union Company also announces that time signals will be furnished from the Naval Observatory at any hour desired and in accordance with the exact programme we have been using.

I write to you in the matter because I am led to believe that a request from you to the Western Union Company to limit the use of the Naval Observatory signals to the part of the country not already furnished with time signals would have great weight not only with them but also with the railroads themselves. I feel quite sure that if you were aware of the manner in which the National Observatory is being placed before the country in the matter you would be glad to correct some of the impressions that are being sent out.

The way in which the company is to operate in some of the cities will result, I am sure, in bringing more or less discredit on the Observatory time service. "Master clocks," as they are called, are to be established at various places from which time signals are to be sent. As these signals will purport to give the Observatory time the Observatory is certain to come in for the credit of the errors which are sure to come about in any such system.

As the matter is one of very great importance to us I trust that you will be willing to take such action as I have requested.

I am very respectfully,

H. S. Pritchett,

Director Observatory.

B.

U. S. Naval Observatory, Washington, Aug. 27, 1889.

Professor H. S. Pritchett,

Observatory of Washington University, St. Louis, Missouri:

Dear Sir: Upon the receipt of your letter of Aug. 8, 1889, I wrote to the Western Union Telegraph Company, asking for copies of all circulars issued by them in which the Naval Observatory is mentioned. They have sent me three, viz:

1st. Catalogue of self-winding synchronized clocks as furnished by the Self-Winding Clock Company, New York.

2d. Self-winding Clock Company's synchronized clocks and daily time signals.

3d. Synchronized self-winding clocks, corrected daily by telegraphic time signals from the Naval Observatory, Washington. D. C. Also a 4th which, with a very slight modification of title, is the same as No. 2.

In these circulars it is announced that clocks will be corrected daily by signals from the Naval Observatory. The right of the Western Union Company to use our daily signals I cannot dispute; it rests upon an arrangement in existence long before I came to the Observatory and any attempt on my part to restrict them to prescribed limits would be futile.

I presume that the term "rival service" is intended to express the relation between the Western Union Company as transmitters of time, and other persons engaged in the same business. But if you can point out to me that the expression has been used to convey the impression that this Observatory can be regarded in the light of a rival to any other Observatory in transmitting time, I shall be greatly obliged to you for the information and shall make proper use of it.

Again I shall be obliged to you if you will indicate how I may learn that the Western Union Company has made any other pledge for this Observatory than to transmit daily noon signals (except in case of failure at noon when a later signal will be sent).

Furthermore, I would esteem it a great favor to be informed of any arrangement by which time transmitted by "master clocks," or by any other means than our noon signals, is to be designated as "Washington Observatory Time." I would also thankfully receive information that the Western Union Company has issued any other circulars than those enumerated above, in which this Observatory is mentioned.

I have regarded your letter of August 8 as confidential as far as the Western Union Company is concerned, and have not felt at liberty to acquaint that company of its contents. If, however, you are willing that the letter shall be treated as official, I shall call upon the General Manager of the Western Union for an explanation of the unwarranted use of the name of the Observatory which you assert is being made. Very respectfully,

R. L. Phythian, Captain, U. S. N., Superintendent.

C.

Captain R. L. Phythian, U. S. N.,
Supt. U. S. N. Observatory, Washington, D. C:

DAER SIR: I beg to acknowledge the receipt of your very kind letter of Aug. 27, which I have just received on returning from a month's absence in the West.

The announcements to which I particularly referred were made by local canvassers for the Western Union Company and by the local superintendent in personal letters to railroad managers which were shown to me but of which I, of course, have no copy. These letters, of course, urged the managers of roads using our service to change and promised a service at the same hour and sent in accordance with the programme we use. What I particularly desired to know was whether such signals would be sent from the Observatory at various hours.

Since writing to you, and a few days before my departure for the West, I had an interview with the Western Manager of the telegraph company together with certain representatives of the railroads, which gives me reason to expect that the matter will be arranged in a satisfactory manner. I shall therefore ask that you will consider both my former letter and the present one as personal communications.

Thanking you again for your cordial reply, I am,

Very respectfully yours,
H. S. PRITCHETT.

D.

NAVAL OBSERVATORY, WASHINGTON, NOV. 2, 1889.

DEAR SIRS: Your letter of October 29th has been received and its contents carefully considered. It is observed that a comparison, the nature of which I do not understand, has been made between the (so-called Observatory signals and a Western Union clock; also that the record of Mr. Hamblet's chronograph has played some part in determining corrections to signals received by you. In short, it is apparent that you have been receiving what purports to be Naval Observatory time through devices over which we have no control, and whose use we have at all times discouraged. Under these circumstances I must decline to furnish you with the corrections asked for.

If you will arrange to receive our signal on a chronograph (or in any other approved manner), in your own establishment so that it will be recorded by the impulse sent from this Observatory, without the intervention of transmitting clocks, or other devices, I shall gladly send you from time to time a table of such small errors as occur during long intervals of weather unfavorable for observation, and of the small corrections to the clock's rate found by back interpolation. In other words, I will supply you with corrections to our *direct* signal which will give you time for which we are willing to be responsible.

Very respectfully,
R. L. PHYTHIAN,
Captain U. S. N., Superintendent.

Msssrs. John Bliss & Co.,
128 Front Street, New York, N. Y.

OBSERVATORY LOCAL PATRONAGE.

In reply to the foregoing very remarkable communication THE MESSENGER does not need to say much now. That portion of it referring to Professor Pritchett he will doubtless answer when the time comes. We have obtained his consent to publish his personal and private letters, so as fairly to meet the singular demand of the Superintendent of the United States Naval Observatory. It should also be said that our private letter to the Superintendent of Dec. 6, asking if a certain statement of his position in regard to local observatories was correct or not, portions of which he hastens to print, had not the remotest reference to the article above referred to, for that article was in print before the statement of his position was known. Further, the Superintendent did not *know* who had made the statement of his position, and yet he answers it depending on, and using, private and personal letters in self-defence. This is a piece of official courtesy that THE MESSENGER is very willing to give full credit for, to the Superintendent, not only because he wants it, but also because he demands it accompanying his demands in a private letter with serious threats if we do not publish "every word" just as he had written it. The Superintendent is evidently much troubled about something.

Now we want to say to the Superintendent that we are not frightened by his threats, nor are we satisfied with the logic of his answer to our article. Attention is called to his replies to points at issue.

1. We have said there are definite contract relations existing between the Western Union Telegraph Company and the Superintendent of the United States Naval Observatory for the Washington time, for the telegraph company's uses in commercial sale and barter. The Superintendent says this statement is "absolutely without foundation;" but does admit that an "*arrangement*" exists by which the Western Union uses the Washington time signals. Fine distinction! Not a contract but an "*arrangement.*" Is the Superintendent driven in his answer to play with words? Whatever he may say about a contract or an "arrangement," a general officer of the telegraph company says there is a contract. Now, in fact, it does not matter at all

whether this contract is in written or verbal form, the telegraph company is now using its privileges to destroy existing local support for local observatories, and we have reason to believe that the Superintendent knows the main facts in the case and does not choose to interfere.

2. How has this late interest in spreading the Washington time all over the country come about?

We call the attention of our readers to the printed proceedings of the General Time Convention held in New York City April 11 and October 10, 1889. At both of these meetings Commander Brown, from the United States Naval Observatory was present. At the first meeting he made extended remarks before the convention urging the general use of the Observatory time, and suggesting that if railway officials needed information, and could not visit Washington doubtless on application some one would be sent to put them in possession of that which they desired to know. At the October meeting Commander Brown reported that he was "prepared to give the time" (meaning the Washington time from the Naval Observatory) "at any hour between 10 o'clock A. M. and midnight that may suit any member of the convention who may ask for it. Before 10 o'clock they have to check up their operations" (observations, probably,) "so as to give the time properly," etc. Why is Commander Brown sent out to these meetings of railway officials? Why is he offering the Washington time and pledging that the Western Union Telegraph Company will transmit this time to any railroad company, using the telegraph company's wires entirely free of charge? Did the Superintendent of the Naval Observatory know anything about this, or was it an "arrangement" made before the time of his administration which began in 1886? That October printed report says (p. 23) that arrangements have been perfected between the United States Observatory at Washington and the Western Union Telegraph Company, by which standard time can be obtained by any (railroad) company reached by the wires of the telegraph company, *without charge* (italics ours), by application to the latter. This plainly shows the position of the Superintendent of the United States Naval Observatory.

3. There are some other steps in this interesting program that we can now only refer to for want of space. The fol-

lowing queries will suggest them: When was the salary of the instrument maker to the Naval Observatory raised? How many times, and by whose recommendation? When did this instrument maker sell the rights of his patent electrically controlled clocks to the Bedford Clock Company of New York City? How much money was paid for the general control of this patent? Were there deferred payments of considerable amounts? If so were those deferred payments made dependent in any way on the use of the Washington time? These are some of the queries that interest local Observatories that have honestly earned and are now enjoying a local patronage by furnishing standard time to local railway companies, at their own figures. This local patronage is now menaced by the united action of the United States Naval Observatory and the Western Union Telegraph Company. The letters already received from the oldest and the most prominent Observatories in the United States plainly indicate that THE MESSENGER's word of advice and alarm are timely and worthy of immediate and serious attention.

ON THE STABILITY OF THE RINGS OF SATURN.*

GEORGE W. COAKLEY.†

For THE MESSENGER.

The satellites of Saturn are very much nearer to the rings than the sun and planets are; and the *difference of their distances* from Saturn's centre, and from the different parts of the ring, bears too great a ratio to their mean distances to allow us to take their action on the nearest and farthest points of the ring as a good approximation to their whole disturbing action. It becomes necessary, therefore, to endeavor to take account of the sum total of all their disturbing forces on each half of the ring, in order to estimate their effect in removing the ring's centre from that of Saturn.

Each ring is very thin and flat, and also of narrow breadth when compared with its diameter; and hence it may be supposed to be composed of a number of concentric

---

* Continued from p. 11, No. 81. † Professor of Astronomy in the University of the City of New York.

circles. If the disturbing action of one of the satellites upon one of these narrow circles be determined, it will make known the like action on each of the circles of which the ring is supposed to consist; and therefore determine the action of the satellite on the whole ring. This is, in fact, La Place's mode of treating the action on the ring. Let us take the circular ring situated at the middle of Saturn's exterior ring for the special subject of investigation. The centre of this circular ring is taken at first to coincide with that of the planet, and its radius is R = 2.2115, the equatorial radius of Saturn being the unit. Let A = the mean distance from Saturn's centre, in terms of the same unit, of one of his satellites, Titan for example.

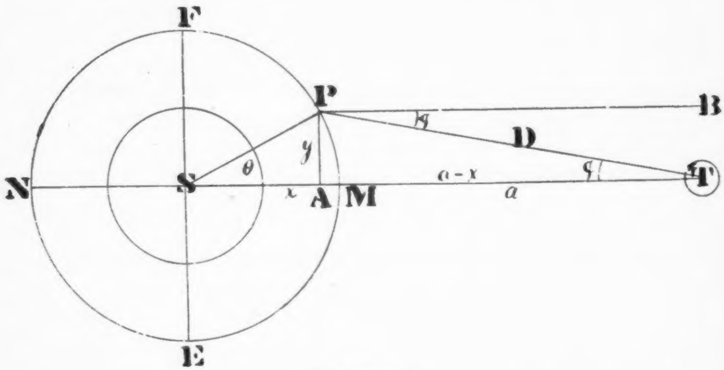

FIGURE 1.

In Fig. I. above, let S be Saturn's centre, and that of the ring; P, any point on the circumference of the middle circle of the exterior ring; SP = R = 2.2115 = the radius of this circle, in terms of Saturn's equatorial radius. Let the inner circle represent Saturn, and T be the position of *any satellite*, Titan for example.

Let $ST = a =$ the mean distance of the satellite, $SA = x$, $AP = y$, the angle $ASP = \vartheta$, measured as an arc on the equator of Saturn; let $PTS = TPB = \varphi$; $PT = D =$ the distance of the point P from the satellite. The element of the circumference at P is $Rd\vartheta$; and if m = the mass of the satellite at T, its attraction on the element at P is $\frac{m \,.\, Rd\vartheta}{D^2}$. If

this force be resolved in the direction of PB, parallel to ST, it will be $\frac{m \,.\, Rd\vartheta}{D^2} \cos\varphi$. The acceleration in the direction of PB will be $\frac{m}{D^2}\cos\varphi$. The acceleration impressed upon Saturn by the satellite, in the direction ST or PB, will be $\frac{m}{a^2}$. Hence the *difference of acceleration* on the element at P, and on Saturn, is $\frac{m}{D^2}\cos\varphi - \frac{m}{a^2}$. This is the force that solicits the element at P away from Saturn's centre, in a direction parallel to ST. There are other components of the satellite's attraction; but they have little or no influence in disturbing the centre of the ring in reference to that of the planet. Hence it is not necessary to consider them. To obtain the sum total of all the disturbing forces, like $\frac{m}{D^2}\cos\varphi - \frac{m}{a^2}$, acting at every point, P, of the semicircle EPF, and at every point of the semicircle, ENF, it is only requisite to multiply the force $\frac{m}{D^2}\cos\varphi - \frac{m}{a^2}$ by $Rd\vartheta$, the element at P, and then integrate, in reference to the variable ϑ, first between the limits $\vartheta = -\frac{\pi}{2}$ and $\vartheta = +\frac{\pi}{2}$, and afterwards between the limits $\vartheta = +\frac{\pi}{2}$ and $\vartheta = +\frac{3\pi}{2}$. Let f_1 denote the first summation, and f_2 the second. Then f_1 will denote the total force of the satellite in drawing away the nearer half of the circular ring from Saturn; but, as f_2 will be negative, showing that the remote half of the ring is virtually driven away from Saturn, the absolute amount of this action will be denoted by $-f_2$, and their ratio will be expressed by $\frac{f_1}{-f_2}$.

But $SA = x = R\cos\vartheta$; $AP = y = R\sin\vartheta$; $AT = a - x = D\cos\varphi$; $AP = y = D\sin\varphi$. Hence $D^2 = (a-x)^2 + y^2 = a^2 - 2ax + x^2 + y^2$.

$$\therefore D^2 = a^2 - 2aR\cos\vartheta + R^2 = a^2\left\{1 - 2\frac{R}{a}\cos\vartheta + \frac{R^2}{a^2}\right\}$$

$$\therefore D = a\left\{1 - 2\frac{R}{a}\cos\vartheta + \frac{R^2}{a^2}\right\}^{\frac{1}{2}}$$

$$\cos\varphi = \frac{a-x}{D} = \frac{a - \mathrm{R}\cos\vartheta}{a\left\{1 - 2\frac{\mathrm{R}}{a}\cos\vartheta + \frac{\mathrm{R}^2}{a^2}\right\}^{\frac{1}{2}}}$$

$$= \frac{1 - \frac{\mathrm{R}}{a}\cos\vartheta}{\left\{1 - 2\frac{\mathrm{R}}{a}\cos\vartheta + \frac{\mathrm{R}^2}{a^2}\right\}^{\frac{1}{2}}}$$

Hence $\frac{m}{D^2}\cos\varphi - \frac{m}{a^2} = \frac{m}{a^2}\cdot\frac{1 - \frac{\mathrm{R}}{a}\cos\vartheta}{\left\{1 - 2\frac{\mathrm{R}}{a}\cos\vartheta + \frac{\mathrm{R}^2}{a^2}\right\}^{\frac{3}{2}}} - \frac{m}{a^2}$

Let $\frac{\mathrm{R}}{a} = \beta$, which may be treated as a *constant*, with a different value, however, for each satellite, since it will answer the purpose of this investigation to treat the orbits of Saturn's satellites as *circles*, each with a different radius, a.

Hence

$$\frac{M}{D^2}\cos\varphi - \frac{m}{a^2} = \frac{m}{a^2}.\left\{(1-\beta\cos\vartheta)(1-2\beta\cos\vartheta+\beta^2)^{-\frac{3}{2}} - 1\right\}. \quad (\mathrm{A.})$$

Since β is generally a small fraction, less than unity, the expression (A) may be developed in a series of converging terms arranged according to the successive powers of β. It may then be multiplied by $Rd\vartheta$, and the several terms be integrated as far as requisite to get a good approximation to the ratio $\frac{f_1}{-f_2}$.

The development of $(1 - 2\beta\cos\vartheta + \beta^2)^{-\frac{3}{2}}$ is

$$1 + 3\cos\vartheta\,.\,\beta - \tfrac{3}{2}(1 - 5\cos^2\vartheta)\,.\,\beta^2 - \tfrac{5}{2}(3\cos\vartheta - 7\cos^3\vartheta)\,.\,\beta^3$$
$$+ \tfrac{15}{8}(1 - 14\cos^2\vartheta + 21\cos^4\vartheta)\,.\,\beta^4 + \tfrac{21}{8}(5\cos\vartheta - 30\cos^3\vartheta$$
$$+ 33\cos^5\vartheta)\,.\,\beta^5$$
$$- \tfrac{7}{16}(5 - 135\cos^2\vartheta + 495\cos^4\vartheta - 429\cos^6\vartheta)\,.\,\beta^6$$
$$- \tfrac{9}{16}(35\cos\vartheta - 385\cos^3\vartheta + 1001\cos^5\vartheta - 715\cos^7\vartheta)\,.\,\beta^7$$
$$+ \tfrac{45}{128}(7 - 308\cos^2\vartheta + 2002\cos^4\vartheta - 4004\cos^6\vartheta$$
$$+ 2431\cos^8\vartheta)\,.\,\beta^8 + \text{etc.}$$

Hence $(1 - \beta\cos\vartheta)(1 - 2\beta\cos\vartheta + \beta^2)^{-\frac{3}{2}} - 1 = 2\cos\vartheta\,.\,\beta$

$$-\tfrac{3}{2}(1 - 3\cos^2\vartheta)\,.\,\beta^2$$
$$- 2(3\cos\vartheta - 5\cos^3\vartheta)\,.\,\beta^3 + \tfrac{5}{8}(3 - 30\cos^2\vartheta + 35\cos^4\vartheta)\,.\,\beta^4$$
$$+ \tfrac{3}{4}(15\cos\vartheta - 70\cos^3\vartheta + 63\cos^5\vartheta)\,.\,\beta^5$$

$$-\tfrac{7}{16}(5 - 105\cos^2\vartheta + 315\cos^4\vartheta - 231\cos^6\vartheta)\,.\,\beta^6$$
$$-\tfrac{1}{2}(35\cos\vartheta - 315\cos^3\vartheta + 693\cos^5\vartheta - 429\cos^7\vartheta)\,.\,\beta^7$$
$$+\tfrac{9}{128}(35 - 1260\cos^2\vartheta + 6930\cos^4\vartheta - 12012\cos^6\vartheta + 6435\cos^8\vartheta)\,.\,\beta^8 + \text{etc.}, = \frac{a^2}{mR}\cdot\frac{df}{d\vartheta}.$$

The integral of the last equation, in reference to ϑ as the variable, gives:

$$\begin{aligned}\frac{a^2}{mR}\cdot f = C &+ 2\sin\vartheta\,.\,\beta + \tfrac{3}{4}(\vartheta + 3\sin\vartheta\cos\vartheta)\,.\,\beta^2\\
&+ \tfrac{2}{3}(\sin\vartheta + 5\sin\vartheta\cos^2\vartheta)\,.\,\beta^3\\
&+ \tfrac{5}{64}(9\vartheta - 15\sin\vartheta\cos\vartheta + 70\sin\vartheta\cos^3\vartheta)\,.\,\beta^4\\
&+ \tfrac{1}{20}(29\sin\vartheta - 98\sin\vartheta\cos^2\vartheta + 189\sin\vartheta\cos^4\vartheta)\,.\,\beta^5\\
&+ \tfrac{7}{256}(25\vartheta + 105\sin\vartheta\cos\vartheta - 490\sin\vartheta\cos^3\vartheta + 616\sin\vartheta\cos^5\vartheta)\,.\,\beta^6\\
&+ \tfrac{1}{70}(53\sin\vartheta + 639\sin\vartheta\cos^2\vartheta - 2277\sin\vartheta\cos^4\vartheta + 2145\sin\vartheta\cos^6\vartheta)\,.\,\beta^7\\
&+ \tfrac{9}{16384}(1225\vartheta - 3255\sin\vartheta\cos\vartheta + 51590\sin\vartheta\cos^3\vartheta\\
&\quad - 136136\sin\vartheta\cos^5\vartheta + 102960\sin\vartheta\cos^7\vartheta)\,.\,\beta^8 + \text{etc.}\end{aligned}$$

Hence, between the limits $-\tfrac{1}{2}\pi$ and $+\tfrac{1}{2}\pi$,

$$\frac{a^2}{m\mathrm{R}}\cdot f_1 = 4\,.\,\beta + \tfrac{3}{4}\pi\,.\,\beta^2 + \tfrac{4}{3}\beta^3 + \tfrac{45}{64}\pi\,.\,\beta^4 + \tfrac{29}{10}\beta^5 + \tfrac{175}{256}\,.\,\pi\,.\,\beta^6 + \tfrac{53}{35}\beta^7 + \tfrac{11025}{16384}\,.\,\pi\,.\,\beta^8 + \text{etc.}$$

And between the limits $\tfrac{1}{2}\pi$ and $\tfrac{3}{2}\pi$

$$\frac{a^2}{m\mathrm{R}}\cdot f_2 = -4\,.\,\beta + \tfrac{3}{4}\pi\,.\,\beta^2 - \tfrac{4}{3}\beta^3 + \tfrac{45}{64}\pi\,.\,\beta^4 - \tfrac{29}{10}\beta^5 + \tfrac{175}{256}\pi\,.\,\beta^6 - \tfrac{53}{35}\,.\,\beta^7 + \tfrac{11025}{16384}\,.\,\pi\,.\,\beta^8 - \text{etc.}$$

The two last equations may be more conveniently written

$$\frac{a^2}{4m\beta\mathrm{R}}\cdot f_1 = 1 + \tfrac{3}{16}\pi\,.\,\beta + \tfrac{1}{3}\beta^2 + \tfrac{45}{256}\pi\beta^3 + \tfrac{29}{40}\beta^4 + \tfrac{175}{1024}\pi\,.\,\beta^5 + \tfrac{53}{140}\beta^6 + \tfrac{11025}{65536}\pi\,.\,\beta^7 + \text{etc.}$$

$$-\frac{a^2}{4m\beta\mathrm{R}}\cdot f_2 = 1 - \tfrac{3}{16}\pi\beta + \tfrac{1}{3}\beta^2 - \tfrac{45}{256}\pi\,.\,\beta^3 + \tfrac{29}{40}\beta^4 - \tfrac{175}{1024}\pi\,.\,\beta^5 + \tfrac{53}{140}\beta^6 - \tfrac{11025}{65536}\pi\,.\,\beta^7 - \text{etc.}$$

Hence the ratio of f_1 to $-f_2$ is

$$\frac{f_1}{-f_2} = \frac{1 + \frac{3}{16}\pi.\beta + \frac{1}{3}\beta^2 + \frac{45}{256}\pi\beta^3 + \frac{29}{40}\beta^4 + \frac{175}{1024}\pi.\beta^5 + \frac{53}{140}\beta^6 + \frac{11025}{65536}\pi\beta^7\ \&c}{1 - \frac{3}{16}\pi.\beta + \frac{1}{3}\beta^2 - \frac{45}{256}\pi\beta^3 + \frac{29}{40}\beta^4 - \frac{175}{1024}\pi.\beta^5 + \frac{53}{140}\beta^6 - \frac{11025}{65536}\pi\beta^7\ \&c}$$

Let $A_1 = \frac{3}{16}\pi$, $A_2 = \frac{1}{3}$, $A_3 = \frac{45}{256}\pi$, $A_4 = \frac{29}{40}$, $A_5 = \frac{175}{1024}\pi$, $A_6 = \frac{53}{140}$, $A_7 = \frac{11325}{65536}\pi$. Then

$$\frac{f_1}{-f_2}=\frac{1+A_1.\beta+A_2.\beta^2+A_3.\beta^3+A_4.\beta^4+A_5.\beta^5+A_6.\beta^6+A_7.\beta^7+\text{etc.}}{1-A_1.\beta+A_2.\beta^2-A_3.\beta^3+A_4.\beta^4-A_5.\beta^5+A_6.\beta^6-A_7.\beta^7+\text{etc.}};$$

and $\log A_1=\bar{1}.7701519$, $\log A_2=\bar{1}.5228787$,
$\log A_3=\bar{1}.7421224$, $\log A_4=\bar{1}.8603380$,
$\log A_5=\bar{1}.7298879$, $\log A_6=\bar{1}.5781479$,
$\log A_7=\bar{1}.7230486$.

Since $R = 2.2115$, and for Saturn's first satellite, Mimas, $a = 3.3$, hence $\beta=\frac{2.2115}{3.3}$,

$\log R = 0.3446869$
$\log a = 0.5185139$
$\therefore \log \beta = \bar{1}.8261730$

For the second satellite, Enceladus, $\log a = 0.6334685$
$\therefore \log \beta = \bar{1}.7112184$

For the third satellite, Tethys, $\log a = 0.7242759$
$\therefore \log \beta = \bar{1}.6204110$

For the fourth satellite, Dione, $\log a = 0.8325089$
$\therefore \log \beta = \bar{1}.5121780$

For the fifth satellite, Rhea, $\log a = 0.9777236$
$\therefore \log \beta = \bar{1}.3669633$

For the sixth satellite, Titan, $\log a = 1.3159703$
$\therefore \log \beta = \bar{1}.0287166$

For the seventh satellite, Hyperion, $\log a = 1.4281348$
$\therefore \log \beta = \bar{2}.9165521$

For the eighth satellite, Japetus, $\log a = 1.8088859$
$\therefore \log \beta = \bar{2}.5358010$

From the values of the logarithms of β, for the several satellites, together with the preceding values of $\log A_1$, $\log A_2$, etc., and the formula for $\frac{f_1}{-f_2}$ the following table has been computed:

		$\frac{f_1}{-f_2}$			$\frac{f_1}{-f_2}$
1st Satellite	Mimas	3.00321	5th Satellite	Rhea	1.32994
2d "	Enceladus	2.08252	6th "	Titan	1.13530
3d "	Tethys	1.74577	7th "	Hyperion	1.10262
4th "	Dione	1.51191	8th "	Japetus	1.04132

The summation of the series, to determine the ratio of f_1 to $-f_2$, has probably not been carried far enough to give a good approximation to this ratio for the first two satellites. But still it gives with sufficient accuracy the *character* of the disturbing action of these satellites upon the ring. This ac-

tion is of the same nature, though relatively larger, as that of the other six satellites. In the case of these last six satellites, the summation as far as the fourth power of β gives very nearly, or within one per cent, of the same values of $\frac{f_1}{-f_2}$ as that obtained by continuing the computation to the seventh power of β. All these results show that the action of the satellites is greater on the nearer half of the ring than on the remote half; and that they thus tend to draw the centre of the ring away from Saturn towards their own direction. But, *if the ring be liquid or fluid*, each satellite also tends to raise tides in the ring in the line of its action; greater, however, on the nearer half than on the remote half, *exactly in proportion to the excess of action that tends to remove the ring's center from that of Saturn*. This is one of the most important conclusions arrived at in reference to the stability of the rings. It will be found, I think, that their stability depends entirely upon this principle of the *relative tides* that the satellites and other disturbing bodies may produce upon the near and remote halves of a liquid or fluid ring.

How the stability of one of the rings may be determined by the tidal action of a satellite, or other disturbing body, is the next subject for investigation.

In Fig. 2 let S be the centre of Saturn, $SF = SH = 1 =$ his equatorial radius; and suppose the centre of one of his rings to be drawn away from that of Saturn to C, a very small distance, by the attraction of one of the satellites, or by the sun, or by one of the major planets. Let $CI_1 = CI_2 =$ the radius of the middle of the ring. Through S and C let a straight line be drawn, and let HSF be perpendicular to this line. Through S draw also the two straight lines AE, BD, including the angle ϑ, measured on the circumference of Saturn. Let $SA = R_1$, $SE = R_2$. The lines AE and BD intercept arcs, $AB = l_1$, and $DE = l_2$, on the middle circle of the ring, such that $l_1 = R_1.\vartheta$, $l_2 = R_2.\vartheta$. Let m_1 and m_2 be the masses of the segments AB and DE, cut off by the planes through AE and DE perpendicular to the plane of the ring. Also let a_1 and a_2 be the areas of the cross sections of these two segments respectively. Then if $\delta =$ the density of the ring in all its parts, the masses of these segments will be, $m_1 = a_1 l_1 \delta$,

$m_2 = a_2 l_2 \delta$. Hence, replacing l_1 and l_2 by their values, $m_1 = \vartheta\delta a_1 R_1$; $m_2 = \vartheta\delta a_2 R_2$.

The lines *AE, BD,* are supposed to be drawn at a small inclination, ϑ, to each other, but at any inclination to *FH*.

If $M =$ Saturn's mass, his attraction for the nearer segment is $\frac{M}{R_1{}^2}$ and the accelerative force of this segment on Saturn is $\frac{M_1}{R_1{}^2}$. Hence the whole accelerative force between Saturn and this nearest segment is $F_1 = \frac{M + m_1}{R_1{}^2}$

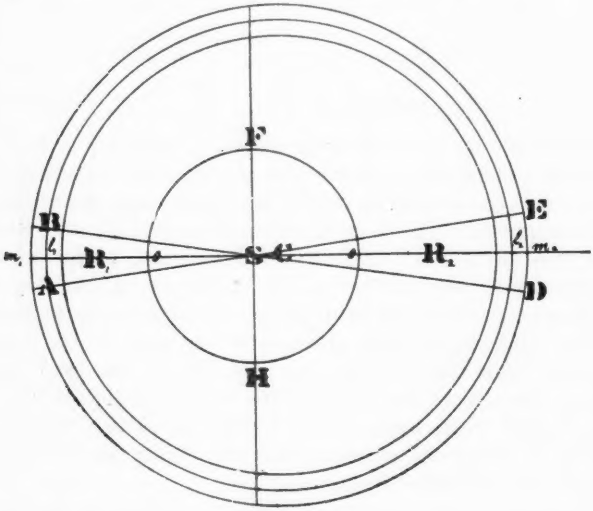

FIGURE 2.

The accelerative force between Saturn and the more distant segment towards the disturbing body is $F_2 = \frac{M + m^2}{R_2{}^2}$

Replacing m_1 and m_2 by their values, these forces become

$$F_1 = \frac{M}{R_1{}^2} + \vartheta\delta \cdot \frac{a_1}{R_1}$$

$$F_2 = \frac{M}{R_2{}^2} + \vartheta\delta \cdot \frac{a_2}{R_2}$$

The differences of these forces is

$$F_1 - F_2 = M \cdot \left(\frac{1}{R_1{}^2} - \frac{1}{R_2{}^2}\right) + \mathfrak{S}\delta \cdot \left(\frac{a_1}{R_1} - \frac{a_2}{R_2}\right) \qquad \text{(I)}$$

The density of the ring, δ, has been supposed to be the same in all its parts, and hence it is so in the two small segments. If, therefore, the cross-section of the ring has always the same area, it will be uniform and homogeneous; and whether solid or liquid, we may in such case replace a_2 by its equal a_1; and shall then have

$$F_1 - F_2 = M \left\{\frac{1}{R_1{}^2} - \frac{1}{R_2{}^2}\right\} + \mathfrak{S}\delta a_1 \cdot \left\{\frac{1}{R_1} - \frac{1}{R_2}\right\} \qquad \text{(II)}$$

But since R_2 is greater than R_1, it follows that $\frac{1}{R_1}$ is greater than $\frac{1}{R_2}$, and hence $\frac{1}{R_1{}^2} > \frac{1}{R_2{}^2}$. The whole second member of (II) is therefore *positive*. Hence $F_1 > F_2$. The mutual attraction between the planet and the nearer segment surpasses that between the planet and the more distant segment. The same is true in this case for any pair of opposite segments included between any two planes through S, inclined in any manner to *FSH*. Hence, in this case of a uniform and homogeneous ring, the whole attraction between the planet and the nearer portion of the ring is greater than that between the planet and the remote portion. The consequence is that the nearer portion of the ring is continually drawn down towards the planet, with accelerated velocity, the center of the ring flying away from the planet, as if repelled by it.

This consequence, however, holds good only on the supposition that the ring is of uniform dimensions, and constant density, in all its parts. It is the case of La Place's homogeneous, uniform solid ring. But the conclusion holds good equally for a liquid or fluid ring, provided it is obliged to preserve the same area of cross-section, $a_1 = a_2$, as well as the same density.

But the ring is revolving around Saturn, and its centre must be carried around him also with a velocity that produces a centrifugal force applied to this centre. This centrifugal force, combined with the repulsive force with which the centre of the uniform ring is driven away from that of

Saturn, must produce a motion, as La Place points out, convex to the centre of Saturn. The orbital motion of the ring, under these circumstances, only helps the more swiftly to drive away its centre from that of the planet, and to precipitate the ring upon the planet with a more violent collision.

Thus the unstable equilibrium of any uniform, homogeneous ring revolving about any planet is demonstrated, if it be subject to the external attraction of any other body.

Professor Peirce's idea was, that the several satellites of Saturn, some of them revolving rapidly around him, might, by their different attractions in different and continually changing directions, help to bring back the ring's centre to that of the planet, and thus restore the equilibrium to stability. But suppose the eight satellites, at a certain moment of time, to have any given arrangement around Saturn. They would then constitute eight given disturbing forces, of different intensities, in eight given directions. There would necessarily be a certain resultant of these eight forces in a certain direction. Unless this resultant were always zero, with every possible arrangement or configuration of the satellites, the resultant disturbing force, in some particular direction, would remove the ring's centre away from that of Saturn, in the direction of that resultant. Long before the direction and amount of that resultant could be reversed, in order to destroy its effect, the centre of the ring will have gone so far from that of the planet, that the inverse square of the distances, together with the great mass of Saturn, would forbid the possibility of repairing the mischief of the disturbing force. A uniform, homogeneous ring, whether solid or fluid, cannot therefore continue to revolve around a planet, with stable equilibrium, in the presence of external disturbing forces.

But we have seen that if the ring be liquid, or fluid, the action of each satellite, or other disturbing body, while it tends to draw away the ring's centre from Saturn toward the disturbing body, tends at the same time to produce in the ring opposite tidal elevations in the line of its action. Moreover, the tidal elevation, on the side of the ring nearest the disturbing body, exceeds that in the remotest part of the ring, *exactly in the same ratio as the two disturbing forces,*

which by their difference tend to withdraw the ring's centre from that of the planet.

The consequence of this state of things is, that when the centre of the ring, C, moves toward the disturbing satellite, and away from Saturn's centre, the superior tidal effect at m_2, nearest the satellite, above that farthest from the satellite, at m_1, will cause the nearer cross-section, a_2, to be greater than the remote one, a_1. Therefore we have $a_2 > a_1$.

Hence, in equation (I), while R_1 and R_2 are still nearly equal, it is possible to have $\frac{a_2}{R_2}$ greater than $\frac{a_1}{R_1}$, so that the second term, $\vartheta\delta\left\{\frac{a_1}{R_1} - \frac{a_2}{R_2}\right\}$, shall be *negative.*

If this negative term be then equal to, or a little greater than, the small positive term $M\left\{\frac{1}{R_1^2} - \frac{1}{R_2^2}\right\}$ as may well be the case when R_2 is very nearly equal to R_1, the effect will be to make $F_1 = F_2$, or $F_1 > F_2$. In this case the centre, C, will be brought back towards the planet's centre and the equilibrium will become stable.

Let us see what will be requisite in order to make $F_1 = F_2$ or $F_1 - F_2 = 0$.

In this case equation (I) will become

$$M\left\{\frac{1}{R_1^2} - \frac{1}{R_2^2}\right\} + \vartheta\delta\left\{\frac{a_1}{R_1} - \frac{a_2}{R_2}\right\} = 0.$$

$$\therefore \vartheta\delta\frac{a_2}{R_2} = \vartheta\delta . \frac{a_1}{R_1} + M\left\{\frac{1}{R_1^2} - \frac{1}{R_2^2}\right\}$$

$$\therefore a_2 = \frac{R_2}{R_1} . a_1 + \frac{M}{\vartheta\delta} . \left\{\frac{1}{R_1} . \frac{R_2}{R_1} - \frac{1}{R_2}\right\}. \qquad \text{(III.)}$$

It is evident from (III) that when R_2 and R_1 are still very nearly equal, so that $R_2 = R_1 + \triangle R$, $\triangle R$ being very small compared with R_1, it follows that

$$a_2 = \left\{1 + \frac{\triangle R}{R_1}\right\} . a_1 + \frac{M}{\vartheta\delta} . \left\{\frac{1}{R_1}\left\{1 + \frac{\triangle R}{R_1}\right\} - \frac{1}{R_1 + \triangle R}\right\}$$

$$\therefore a_2 = a_1 + a_1 . \frac{\triangle R}{R_1} + \frac{M}{\vartheta\delta}\left\{\frac{1}{R_1} + \frac{\triangle R}{R_1^2} - \frac{1}{R_1}\left\{1 + \frac{\triangle R}{R_1}\right\}^{-1}\right\}$$

Retaining only the first power of the small fraction $\frac{\triangle R}{R_1}$ it follows that

$$a_2 = a_1 + a_1 \cdot \frac{\triangle R}{R_1} + \frac{2M}{\vartheta\delta} \cdot \frac{\triangle R}{R_1{}^2}$$

It is thus evident that a very small increase of a_2 over a_1 is sufficient, when $\triangle R$ is very small in comparison with R_1, to make the force F_1 equal to F_2; and a very slight additional increase of a_2 over a_1 will make F_2 greater than F_1. This slight additional increase of a_2 over a_1, which the tidal action of each satellite seems abundantly able to provide in its action on a fluid ring, will tend to restore the centre of the ring to that of the planet, thus maintaining the equilibrium in a *stable condition.*

It is now evident that, not only each satellite, but the sun, or any planet, by the same reasoning, furnishes separately, and in just measure, the bane and antidote for destroying and restoring the stability of equilibrium of the rings of Saturn, *on the sole condition of their being fluid*, and therefore subject to a *tidal change of figure.* Perhaps also, the difference of action of the satellites on the outer and inner edge, and on the middle of the rings, may account for their temporary openings, and subsequent closing up, as observed by Mr. George P. Bond and others.

DOUBLE-STAR OBSERVATIONS AT THE WASHBURN OBSERVATORY.

GEORGE C. COMSTOCK.*

For THE MESSENGER.

The double-star observations made with the 15½-inch equatorial of the Washburn Observatory during the years 1888-89 are now nearly ready for publication, but as some months must elapse before the volume containing them can be distributed, it has seemed proper to comply with the request of the editor of THE SIDEREAL MESSENGER for astronomical news, and to present here some of the more interesting results of the observations of that series.

The stars observed are chiefly those discovered at the Washburn Observatory during the years 1881-4, and a principal purpose of the work has been to select from this list of

* Director of Washburn Observatory, Madison, Wis.

more than 250 stars, those interesting on account of rapid relative motion or other peculiarity. The only observations available for comparison with my own are those made by Mr. Burnham in 1881, and the interval of time between his observations and mine being only seven years, it is evident that only large relative motions can be detected by a comparison of our results. It is well known that observers differ among themselves to a marked degree in the measurement of position angles and distances, *i. e.*, there is a *personal equation* which must be allowed for, before the observations of two different observers can properly be compared with each other. This *personal equation* between Mr. Burnham and myself, I have derived from a comparison of 135 double-stars which we have observed in common, and in deriving relative motion of the components of a double-star, I have in all cases reduced my measures to his standard by applying the *personal equation* thus determined.

The following list shows all of the cases in which a relative motion seems assured:

Ll. 4370; R. A. = $2^h\,16^m.8$; Decl. = + 57°40′; Mags. 8-10.

1881.56	$p = 186°.5$	$s = 1''.78$	Observed 3 nights.
1888.11	186 .4	2 .31	" 3 "

β 794; R. A. = $11^h\,47^m.2$; Decl. = + 74°26′; Mags. 7-8.

1881.34	$p = 106°.6$	$s = 0''.42$	Observed 5 nights.
1889.19	131 .2	0 .41	" 4 "

β 800; R. A. = $13^h\,10^m.8$; Decl. = + 17°40′; Mags. 7-10.

1881.36	$p = 121°.5$	$s = 1''.26$	Observed 4 nights.
1888.39	120 .2	2 .22	" 3 "

β 815; R. A. = $16^h\,23^m.3$; Decl. = + 43°11′; Mags. 8-10.

1881.30	$p = 348°.4$	$s = 6''.39$	Observed 3 nights.
1888.54	343 .3	7 .35	" 3 "

S. D. 14°; 4712; R. A. = $17^h\,31^m.7$; Decl. = − 14°46′; Mags. 9-9.

1881.38	$p = 338°.2$	$s = 1''.37$	Observed 2 nights.
1888.60	333 .4	1 .74	" 3 "

β 838; R. A. = $21^h\,14^m.8$; Decl. = + 2°37′; Mags. 8-9.

1881.66	$p = 90°.3$	$s = 1''.28$	Observed 3 nights.
1887.77	97 .1	1 .56	" 3 "

β 848; R. A. = $22^h\,50^m.0$; Decl. = + 57°44′; Mags. 8-11.

1881.67	$p = 5°.8$	$s = 2''.76$	Observed 3 nights.
1888.40	2 .4	2 .36	" 2 "

D.M. 38°; 5112; R. A. = $23^h\,55^m.3$; Decl. = + 38°58′; Mags. 8-9.

1881.71	$p = 124°.1$	$s = 0''.62$	Observed 3 nights.
1888.17	105 .5	0 .49	" 2 "

A triple star interesting by reason of the closeness of all of the components is:

S. D. 14°; 1171; R. A. $= 5^h 28^m.6$; Decl. $= -14°27'$.

This was recognized as a double-star by Professor Holden in 1882 or 1883, the exact date I cannot find. The star was not measured, but the estimated position of the components was $p = 230°$ $s = 1''$, magnitudes 10–10. I measured the star twice in 1888 without noting anything peculiar except that the definition appeared worse than in the case of other neighboring stars, but subsequently I found a minute companion between the principal components. The positions are:

	Stars A and B.		
1888.55	$p = 219°.6$	$s = 2''.76$	Observed 4 nights.
	Stars A and C.		
1888.91	$p = 252°.2$	$s = 1''.80$	Observed 2 nights.

making this an unusually close triple star.

ON THE SPECTRUM OF ζ URSÆ MAJORIS.*

EDWARD C. PICKERING.

In the Third Annual Report of the Henry Draper Memorial, attention is called to the fact that the K line in the spectrum of ζ Ursæ Majoris occasionally appears double. The spectrum of this star has been photographed at the Harvard College Observatory on seventy nights and a careful study of the results has been made by Miss A. C. Maury, a niece of Dr. Draper. The K line is clearly seen to be double in the photographs taken on March 29, 1887, on May 17, 1889 and on August 27 and 28, 1889. On many other dates the line appeared hazy, as if the components were slightly separated, while at other times the line appears to be well defined and single. An examination of all the plates leads to the belief that the line is double at intervals of 52 days, beginning March 27, 1887, and that for several days before and after these dates it presents a hazy appearance. The doubling of the line was predicted for October 18, 1889, but only partially verified. The line appeared hazy or

* Read at the Philadelphia meeting of the Nat. Acad. of Sciences Nov. 13, 1889.

slightly widened on several plates but was not certainly doubled. The star was however low and only three prisms could be used, while the usual number was four. The predicted times at which the line should be again double are on December 9, 1889, and on January 30, 1890. The hydrogen lines of ζ Ursæ Majoris are so broad that it is difficult to decide whether they are also separated into two or not. They appear, however, to be broader when the K line is double than when it is single. The other lines in the spectrum are much fainter, and although well shown when the K line is clearly defined, are seen with difficulty when it is hazy. Several of them are certainly double when the K line is double. Measures of these plates gave a mean separation of 0.246 millionths of a millimeter for a line whose wave-length is 448.1 when the separation of the K line whose wave-length is 393.7, was 0.199. The only satisfactory explanation of this phenomenon as yet proposed is that the brighter component of this star is itself a double-star having components nearly equal in brightness and too close to have been separated as yet visually. Also that the time of revolution of the system is 104 days. When one component is approaching the earth all the lines in its spectrum will be moved toward the blue end, while all the lines in the spectrum of the other component will be moved by an equal amount in the opposite direction if their masses are equal. Each line will thus be separated into two. When the motion becomes perpendicular to the line of sight the spectral lines recover their true wave-length and become single. An idea of the actual dimensions of the system may be derived from the measures given above. The relative velocity as derived from the K line will be 0.199 divided by its wave-length 393.7 and multiplied by the velocity of light 186,000 which is equal to 94 miles a second. A similar calculation for the line whose wave-length is 448.1 gives 102 miles per second. Since the plates were probably not taken at the exact time of maximum velocity these values should be somewhat increased. We may, however, assume this velocity to be about one hundred miles per second. If the orbit is circular and its plane passes through the sun, the distance traveled by one component of the star regarding the other as fixed would be 900 million miles, and the distance

apart of the two components would be 143 million miles, or about that of Mars and the sun. The combined mass would be about forty times that of the sun to give the required period. In other words, if two stars each having a mass twenty times that of the sun revolved around each other at a distance equal to that of the sun and Mars, the observed phenomenon of the periodic doubling of the lines would occur. If the orbit was inclined to the line of sight its dimensions and the corresponding masses would be increased. An ellipticity of the orbit would be indicated by variations in the amount of the separation of the lines, which will be considered hereafter. The angular distance between the components is probably too small to be detected by direct observation. The greatest separation may be about 1.5 times the annual parallax. Some other stars indicate a similar peculiarity of spectrum, but in no case is this as yet established.

Harvard College Observatory,
Cambridge, U. S., Nov. 12, 1889.

ADDENDA.—Dec. 17. The predicted doubling of the lines of ζ Ursæ Majoris on December 8th was confirmed on that day by each of three photographs. Two more stars have been found showing a similar periodicity: β Aurigæ and *b* Ophiuchi (H. P. 1100 and 2909).

Jan. 11, 1890. Later observations make it probable that the period of ζ Ursæ Majoris is 52 days instead of 104, and that its orbit is noticeably elliptical. The velocity of the components of β Aurigæ seems to be 150 miles per second, their period 4 days, their orbit nearly circular, with a radius of 8,000,000 miles, and their masses 0.1 or 0.2, that of the sun being unity.

Queries. 1. What is the equation, in Cartesian co-ordinates, of an ellipse passing through five points, x_1y_1; x_2y_2; x_3y_3; x_4y_4; x_5y_5, or the simplest way of forming it?

2. Given the elements of the orbit of a binary star, how should the orbital velocity in the line of sight vary (*a*) as the position-angle varies, (*b*) at each epoch during the period of the system? QUERIST.

A complete answer to the first query will furnish the means of determining the orbit of a binary star from five observations. The second branch of the second query is needed, for a star like Algol, where one can not observe the position-angle, and can only note the time of observations with the spectroscope.

CURRENT CELESTIAL PHENOMENA.

THE PLANETS.

Mercury was quite conspicuous in the southwest for a few evenings in January. It has now passed inferior conjunction, and will be at greatest elongation west from the sun 26° 50′ on Feb. 23. It will then be farther south than the sun and hence in our latitude will rise only a little over an hour earlier than the sun.

The last number (2944) of the *Astronomische Nachrichten* contains a very important paper on "The Rotation of Mercury," by Professor G. V. Schiaparelli, of the Observatory at Milan, Italy. The paper being written in Italian, which we do not read readily, we cannot give the substance of the paper, but the important conclusions which we have been able to make out are, (1) that Mercury rotates upon its axis once in about 88 days; (2) that the axis of rotation is nearly perpendicular to the plane of the planet's orbit. These conclusions he draws from the discussion of a series of observations made in 1882 and 1883 with the 8-inch refractor (with which he discovered the "canals" of Mars) and verified by observations made in subsequent years with the same instrument and with the new 18-inch refractor. If this period of rotation is correct, Mercury always turns the same side toward the sun, just as the moon always turns the same side to the earth. Professor Schiaparelli finds that, as in the case of the moon, there is a libration in longitude which, owing to the large eccentricity of Mercury's orbit, amounts to about 47°. He gives a map of the dark markings upon the visible surface of the planet, which are so similar to the markings upon his map of Mars as to suggest that possibly Professor Schiaparelli may have a bias for seeing that particular kind of markings.

Venus changes during February from "morning" to "evening star" passing through superior conjunction Feb. 18. During this month she will be too near the rays of the sun to be easily seen.

Mars rises soon after midnight and will soon be in good position for observation in the southern hemisphere. He is too far south in declination for good observations in this latitude. The diameter of his disk on March 1 will be 4.7″ and 0.898 of the illuminated surface will be visible from the earth. Mars passes, this month, through Libra into Scorpio. On March 4 at 10 P. M., central time, he will be within 8′ of the bright star β Scorpii; so close as to be within the same field of view in large telescopes.

Jupiter becomes "morning star" in place of Venus, rising from an hour to two hours earlier than the sun. He may be found near the southeast point of the horizon in this latitude. The last number of the *Monthly Notices* contains reports of the occultation of Jupiter on Aug. 7 last, observed by three observers at the Radcliffe Observatory, and by Captain William Noble at Forest Lodge, Maresfield. Six engravings accompany the reports, showing the shadow on Jupiter's disk parallel to the edge of the moon as seen by three of the observers, two of them noticing it both at immersion and emersion, and while Jupiter was at a short distance from the edge of the moon as well as when in contact with it.

Saturn is now in good position for observation in the evening. He may be easily recognized in the east near the first magnitude star Regulus in the group of the Sickle. The last November number of the *Monthly Notices* contains excellent ephemerides of Saturn's satellites for the first half of this year, by Mr. Marth. The earth is approaching so near to the plane of Saturn's rings and of the satellite orbits that some of the satellites will suffer occultation by the planet and the rings. There may be also eclipses of the satellites in the shadow of the planet. Mr. Marth has indicated the times of such phenomena as closely as the elements of the satellites' orbits will permit. Japetus will be in transit across the ball of the planet March 2 from 3.4 A. M. to 8.8 A. M. central time, entering upon the disk 8″ south and leaving it 6″ south of the center. Mr. Marth says: "As the latitudes of the inner satellites above the plane of the planet's equator, and also the true extent of the shadow-cone, are not known, it is uncertain when the cycles of the eclipses of the several satellites begin. In the case of *Tethys* the first eclipses are not observable from the earth, since they take place while the satellite is hidden by the planet. But in the case of *Dione* the satellite remains outside the planet's disc, and it will be worth while to watch it about the times of the heliocentric conjunctions given in the list, and to observe some of the earlier eclipses, taking care that the times of the observed disappearance and reappearance should refer to similar phases. Observers with powerful telescopes should look out whether, at the predicted time of "Te. n." [Tethys north of planet] in February and March, the shadow of *Tethys* can be discerned on the planet's disc. The conjunctions of *Dione* and *Rhea* with the center of the planet are, during the present apparition of *Saturn*, most favorable for the determination of the orbital longitudes of these satellites, and it would be a pity if the opportunities for observing them were neglected. By timely publication or communication of their observations of such conjunctions and of conjunctions of *Mimas*, *Enceladus*, and *Tethys* with the ends of the ring, observers would have the satisfaction of rendering their contributions available for the proper prediction of the occurrences, which will make the observations of the satellites during the next apparitions of *Saturn* specially interesting."

Uranus may be observed after midnight. He is in Virgo about half way between Spica and the fourth magnitude star Kappa.

Neptune will be at quadrature with the sun Feb. 19, crossing the meridian then at 6 P. M. He is in Taurus about half way on a line between Aldebaran and the Pleiades.

MERCURY.

1890.	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Feb. 24	20 47.0	−18 08	5 40 A.M.	10 28.9 A.M.	3 18 P.M.
Mar. 6	21 36.9	−15 50	5 40 "	10 39.4 A.M.	3 38 "
16	22 34.7	−11 21	5 40 "	10 57.8 "	4 16 "

VENUS.

Feb. 24	22 39.6	−10 01	6 58 A.M.	12 21.3 P.M.	5 45 P.M.
Mar. 6	23 26.1	− 5 12	6 45 "	12 28.3 "	6 11 "
16	0 11.8	− 0 09	6 32 "	12 34.5 "	6 37 "

MARS.

Feb. 24	15 43.9	−18 31	12 40 A.M.	5 26.7 A.M.	10 14 A.M.
Mar. 6	16 01.2	−19 30	12 22 "	5 04.6 "	9 47 "
16	16 16.7	−20 19	12 02 "	4 40.7 "	9 19 "

JUPITER.

	R. A. h m	Decl. ° ′	Rises. h m	Transits. h m	Sets. h m
Feb. 24	20 10.1	−20 23	5 14 A.M.	9 52.2 A.M.	2 30 P.M.
Mar. 6	20 18.7	−19 57	4 41 "	9 21.6 "	2 02 "
16	20 26.7	−19 31	4 08 "	8 50.3 "	1 33 "

SATURN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Feb. 24	10 10.9	+13 05	4 54 P.M.	11 50.7 P.M.	6 47 A.M.
Mar. 6	10 07.9	+13 22	4 11 "	11 08.4 "	6 06 "
16	10 05.2	+13 37	3 28 "	10 26.3 "	5 25 "

URANUS.

	R. A.	Decl.	Rises.	Transits.	Sets.
Feb. 24	13 38.9	− 9 38	9 53 P.M.	3 18.1 A.M.	8 43 A.M.
Mar. 6	13 37.9	− 9 32	9 12 "	2 37.8 "	8 03 "
16	13 36.7	− 9 25	8 31 "	1 57.3 "	7 23 "

NEPTUNE.

	R. A.	Decl.	Rises.	Transits.	Sets.
Feb. 24	4 00.2	+18 56	10 19 A.M.	5 41.0 P.M.	1 04 A.M.
Mar. 6	4 00.6	+18 58	9 40 "	5 02.3 "	12 25 "
16	4 01.3	+19 00	9 01 "	4 23.5 "	11 47 P.M.

THE SUN.

	R. A.	Decl.	Rises.	Transits.	Sets.
Feb. 24	22 31.7	− 9 16	6 46 A.M.	12 13.4 P.M.	5 42 P.M.
Mar. 6	23 09.1	− 5 28	6 29 "	12 11.3 "	5 54 "
16	23 45.8	− 1 32	6 10 "	12 08.7 "	6 07 "

Occultations Visible at Washington.

Date.	Star's Name.	Magnitude.	IMMERSION. Wash. Mean T. h m	IMMERSION. Angle f'm N. P't. °	EMERSION. Wash. Mean T. h m	EMERSION. Angle f'm N. P't. °	Duration. h m
Mar. 6	ν Virginis	4	13 30	82	14 30	347	1 00
9	94 Virginis	6½	11 59	155	12 59	270	1 00

Minima of Variable Stars of the Algol Type.

	R. A. h m s	Decl. ° ′	Range of Magnitude.	Period. h m s	Approx. Central Times of Minima.
U Cephei	0 52 32	+81 17	7.1 to 9.2	2 11 50	Feb. 18, 12ʰ mdn. 23, 12ʰ mid.; 28, 12ʰ mid.; Mar. 5, 11ʰ P. M.; 10, 11ʰ P. M.; 15, 11ʰ P.M.
Algol	3 01 01	+40 32	2.3 to 3.5	2 20 49	Feb. 27, 3ʰ A. M.; Mar. 2, 12ʰ mid.; 4, 9ʰ P.M.; 7, 6ʰ P.M.
λ Tauri	3 54 35	+12 11	3.4 to 4.2	3 22 52	Mar. 7, 11ʰ P. M.; 11, 10ʰ P. M.; 15, 9ʰ P. M.
R Canis Maj	7 14 30	−16 11	5.9 to 6.7	1 03 16	Feb. 17, 7ʰ P. M.; 18, 10ʰ P. M.; 20, 1ʰ A. M.; 26, 9ʰ P. M.; 27, 12ʰ mid.; Mar. 1, 4ʰ A. M.; 6, 8ʰ P. M.; 7, 11ʰ P. M.
S Cancri	8 37 39	+19 26	8.2 to 9.8	9 11 38	Feb. 15, 11ʰ P. M.; Mar. 6, 11ʰ P. M.
δ Libræ	14 55 06	− 8 05	5.2 to 6.2	2 07 51	Feb. 16, 12ʰ mid., 24, 2ʰ A.M.;
U Coronæ	15 13 43	+32 03	7.5 to 8.9	3 10 51	Feb. 18, 11ʰ P. M.; 25, 9ʰ P.M.; Mar. 15, 4ʰ A.M.
U Ophiuchi	17 10 56	+ 1 20	6.0 to 6.7	0 20 08	Feb. 16, 2 A. M.

Phases of the Moon.

			Central Time. d	h	m	
New Moon	1890	Feb.	19	4	28	A. M.
First Quarter	"	"	26	8	06	A. M.
Full Moon	"	Mar.	6	12	47	P. M.
Last Quarter	"	"	13	10	05	P. M.
Perigee	"	Feb.	17	7	42	P. M.
Apogee	"	Mar.	1	9	42	P. M.

Ephemerides of Saturn's Satellites.

[Computed by A. Marth, Monthly Notices R. A. S., vol. L, No. 1, p. 56.]

Feb. 15	11.2 a. m.	Te. n.
	8.5 p. m.	Rh. w.
	8.6 p. m.	Mi. s.
16	3.0 a. m.	En. s.
	9.9 a. m.	Te. s.
	11.7 a. m.	Di. s.
	7.2 p. m.	Mi. s.
	7.4 p. m.	En. n.
	11.6 p. m.	Rh. s.
17	1.8 a. m.	* 8 m. precedes 12.7s. on parallel.
	8.5 a. m.	Te. n.
	5.8 p. m.	Mi. s.
	7.0 p. m.	* 8 m s. 78″
	8.5 p. m.	Di. n.
18	2.7 a. m.	Rh. e.
	7.2 a. m.	Te. s.
	4.4 p. m.	Mi. s.
	8.8 p. m.	En. s.
19	5.3 a. m.	Di. s.
	5.7 a. m.	Rh. n.
	5.8 a. m.	Te. n.
	1.2 p. m.	En. n.
	3.0 p. m.	Mi. s.
20	4.5 a. m.	Te. s.
	5.6 a. m.	Tit. n. 34″
	8.8 a. m.	Rh. w.
	1.6 p. m.	Mi. s.
	2.2 p. m.	Di. n.
	10.1 p. m.	En. n.
21	3.1 a. m.	Te. n
	11.9 a. m.	Rh. s.
	2.5 p. m.	En. s.
	11.0 p. m.	Di. s.
	11.5 p. m.	Mi. n.
22	1.7 a. m.	Te. s.
	3.0 p. m.	Rh. e.
	10.2 p. m.	Mi. n.
	11.4 p. m.	En. s.
23	12.4 a. m.	Te. n.
	7.8 a. m.	Di. n.
	3.8 p. m.	En. n.
	6.1 p m.	Rh. n
	8.8 p. m.	Mi. n.
	11.0 p. m.	Te. s.
24	4.6 p. m.	Di. s.
	7.4 p. m.	Mi. n.
Feb. 24	9.1 p. m.	Rh. w.
	9.7 p. m.	Te. n.
25	12.7 a. m.	En. n.
	5.1 p. m.	En. s.
	6.0 p. m.	Mi. n.
	8.3 p. m.	Te. s.
26	12.2 a. m.	Rh. s.
	1.5 a. m.	Di. n.
	4.6 p. m.	Mi. n.
	7.0 p. m.	Te. n.
27	2.0 a. m.	En. s.
	3.3 a. m.	Rh. e.
	10.3 a. m.	Di. s.
	3.2 p. m.	Mi. n.
	5.6 p. m.	Te. s.
	6.4 p. m.	En. n.
28	6.4 a. m.	Rh. n.
	10.4 a. m.	Tit. s. 36″
	1.8 p. m.	Mi. n.
	4.3 p. m.	Te. n.
	7.1 p. m.	Di. n.
Mar. 1	1.2 a. m.	Mi. s.
	2.8 a. m.	Tit. c. Jap. 19″
	9.5 a. m.	Rh. w.
	2.9 p. m.	Te. s.
	6.3 p. m.	Te. c. Jap. 3″
	7.8 p. m.	En. s.
	11.8 p. m.	Mi. s.
2	3.4 a. m.	Jap. Transit Ingress 8″ s.
	3.9 a. m.	Di. s.
	8.8 a. m.	Jap. Transit Egress 6″ s.
	12.5 p. m.	Rh. s.
	1.6 p. m.	Te. n.
	4.6 p. m.	Jap. c. prec. end of ring 4″ s.
	6.6 p. m.	Mi. c. Jap. 1″
	7.4 p. m.	Mi. c. prec. end of ring 4″
	10.9 p. m.	En. c. Jap. 1″
3	1.5 a. m.	En. c. prec. end of ring 6″
Mar. 3	3.8 a. m.	Te. c. Jap. 3″
	12.2 p. m.	Te. s.
	12.8 p. m.	Di. n.
	3.6 p. m.	Rh. e.
4	10.8 a. m.	Te. n.
	6.7 p. m.	Rh. n.
	9.6 p. m.	Di. s.
5	9.5 a. m.	Te. s.
	9.8 p. m.	Rh. w.
6	6.4 a. m.	Di. n.
	8.1 a. m.	Te. n.
7	12.9 a. m.	Rh. s.
	6.8 a. m.	Te. s.
	3.3 p. m.	Di. s.
8	3.1 a m.	Tit. n. 36″
	4.0 a. m.	Rh. e.
	5.4 a. m.	Te. n.
	4.2 p. m.	En. s.
9	12.1 a. m.	Di. n.
	4.1 a. m.	Te. s.
	7.0 a. m.	Rh. n.
	12.0 mdn.	Mi. n.
10	1.0 a. m.	En. s.
	2.7 a. m.	Te. n.
	8.9 a. m.	Di. s.
	10.1 a. m.	Rh. w.
	5.5 p. m.	En. n.
	10.6 p. m.	Mi. n.
11	1.4 a. m.	Te. s.
	1.2 p. m.	Rh. s.
	5.7 p. m.	Di. n.
	9.2 p. m.	Mi. n.
	12.0 mdn.	Te. n.
12	4.3 p. m.	Rh. e.
	6.8 p. m.	En. s.
	7.8 p. m.	Mi. n.
	10.7 p. m.	Te. s.
13	2.6 a. m.	Di. s.
	11.2 a. m.	En. n.
	6.5 p. m.	Mi. n.
	7.4 p. m.	Rh. n.
	9.3 p. m.	Te n.
14	11.4 a. m.	Di. n.
	5.1 p. m.	Mi. n.
	8.0 p. m.	Te. s.
	8.1 p. m.	En. n.
	10.5 p. m.	Rh. w.

En. = Enceladus; Di. = Dione; Jap. = Japetus; Mi. = Mimas; Rh. = Rhea; Te = Tethys; Tit. = Titan; c. = conjunction; e. = eastern elongation; w. = western elongation; n. = north of center of planet; s. = south of center of planet. The conjunctions of the three innermost planets with the ends of the ring take place in the case of Mimas abou 3.0h, Enceladus, 3.2h, Tethys, 3.5h before and after the predicted conjunctions with the center, which are not observable.

Milton Updegraff, of Cordoba Observatory, Argentine Confederation, South America, in a recent letter, says: "Auwers' list of 480 fundamental stars (for southern zone observations), which I have been working at during the past two years, will be finished within a month or two, and soon after its completion I expect to return to the United States."

COMETS.

Comet 1881 V (Denning). The following ephemeris, from *Astronomische Nachrichten*, No. 2942, p. 222, was computed by Dr. B. Matthiesen, taking account approximately of the perturbations by Jupiter, which in 1887 were very considerable and uncertain in amount. Perihelion passage falls on May 9, but under such unfavorable circumstances that the theoretical brightness of the comet will then be less than one-third its brightness at the time of discovery in 1881, and only a little brighter than when it was last observed in that year. It will be a morning comet, rising at best only an hour and a half earlier than the sun, so that it is extremely doubtful whether it will be detected at this apparition.

1890	α app.	δ app.	log r	log Δ	L.
Feb. 10	$19^h\ 46^m\ 14^s$	$-23°40.4'$	0.2008	0.3782	0.07
14	19 59 19	-23 13.0			
18	20 12 50	-22 40.5	0.1735	0.3546	0.09
22	20 26 49	-22 02.4			
26	20 41 16	-21 18.2	0.1440	0.3305	0.11
Mar. 2	20 56 13	-20 27.6			
6	21 11 40	-19 29.9	0.1122	0.3063	0.15
10	21 27 35	-18 24.6			
14	21 44 01	-17 11.4	0.0782	0.2830	0.19
18	22 10 59	-15 49.8			
22	22 18 27	-14 19.6	0.0420	0.2615	0.25
26	22 36 25	-12 40.6			
30	22 54 52	-10 53.0	0.0040	0.2430	0.32

Comet 1884 II (Barnard's). Since writing the note on this comet last month the *Astronomische Nachrichten*, Nos. 2938-39, have come to hand, containing a definitive determination of the elements by Dr. A. Berberich:

Epoch 1884, Aug. 16.5 Berlin mean time.

$$M = 359°\ 59'\ 49''.13 + 2.50\,d\mu$$

$$\left.\begin{aligned}\omega &= 301\ \ 01\ \ 58\ .63 - 21.10\,d\mu\\ \Omega &= 5\ \ 08\ \ 59\ .12 + 26.44\,d\mu\\ i &= 5\ \ 27\ \ 38\ .40 - 5.53\,d\mu\end{aligned}\right\}\ \text{Mean equinox 1884.0}$$

$$\varphi = 35\ \ 44\ \ 50\ .92 - 98.25\,d\mu$$

$$\mu = 657''.0839 \pm 0''.8876$$

$$\log a = 0.4882572 \qquad a = 3.07791$$

Time of perihelion = 1884 Aug. 16.516543
Period = 1972.35 ± 2.66 days.

This period would have brought the comet to perihelion Jan. 9.87, 1890, but under such unfavorable conditions as to make it impossible to be seen. Since the longitude of the comet at perihelion was 306°, and that of the sun on Jan. 9, 290°, the comet was only 9° east from the sun, and it will remain near the sun for several months. In 1895 it will appear early in May, when the conditions for its re-discovery will be somewhat more favorable.

Comet 1888 III. Elements of the orbit of this comet have been computed by Lieut. Gen. J. T. Tennant (*Monthly Notices*, Nov. 1889, p. 43) from eight normal places, depending upon 179 observations extending from Aug. 9 to Oct. 27. "It would appear that the orbit is really elliptic,

though the eccentricity is very uncertain. Had the comet been discovered a few days sooner and observed about perihelion, we might have had doubts removed."

$$
\begin{aligned}
T &= \text{July } 31.0952 \\
\Omega &= 101^\circ\ 30'\ 11'' \\
\pi &= 160\ \ 38\ \ 50 \\
i &= \ \ 74\ \ 12\ \ 23 \\
\log q &= 9.9550614 \qquad q = 0.901704 \\
\varepsilon &= 0.9979
\end{aligned}
$$

Comet 1889 II. Professor E. Millesovich has computed elements of this comet from the observations of date March 31, April 29, August 29, and October 23, which represent an observation made at Vienna Nov. 21, within the corrections -0.9^s and $-13''$ (*Astr. Nach.* 2941).

$$
\begin{aligned}
T &= 1889 \text{ June } 10.80670 \text{ Berlin mean time.} \\
&\left.\begin{aligned}
\pi &= 186^\circ\ 46'\ 58.4'' \\
\Omega &= 310\ \ 42\ \ 09.7 \\
i &= 163\ \ 50\ \ 26.0
\end{aligned}\right\}\ 1889.0 \\
\log q &= 0.353260;\ q = 2.25559.
\end{aligned}
$$

Comet 1889 VI (Swift, Nov. 17). The orbit of this comet proves to be elliptic and of short period. The elements derived are as yet somewhat uncertain, owing to the very slow motion of the comet. Of the two sets of elements given below, the first, by Rev. George M. Searle, depends upon three observations of dates Nov. 18, 26, and Dec. 13 (*Astr. Jour.* No. 208), the second, by Dr. K. Zelbr (*Astr. Nach.* No. 2944) upon three observations of dates Nov. 19, 29, and Dec. 9. The ephemerides at hand do not extend beyond Jan. 28.

Computer:	Rev. George M. Searle.		Dr. K. Zelbr.	
$T =$	1889 Nov. 29.8212 Gr. M. T.		1889 Nov. 29.66411 Ber. M. T.	
$\pi =$	40° 26′ 03″	1889.0	40° 55′ 52.8″	1889.0
$\omega =$	70 01 05		69 29 12.7	
$\Omega =$	330 24 58		331 26 40.1	
$i =$	10 15 03		10 03 21.1	
$\log q =$	0.31746	$q = 1.3544$		
$\varphi =$	43° 03′ 18″		39 08 23.1	
$\log a =$	0.630275		0.559784	$a = 3.6290$
Period $=$	8.82 years.		6.91 years.	

Comet 1890 (Borrelly 1889 Dec. 12). Mr. G. A. Hill sends the following preliminary elements of this comet, depending upon observations only ten days apart. They do not differ very much from those of other computers so far as received.

$$
\begin{aligned}
T &= 1890 \text{ Jan. } 26.832 \\
&\left.\begin{aligned}
\pi &= 209^\circ\ 38'\ 49'' \\
\omega &= 197\ \ 22\ \ 35 \\
\Omega &= \ \ 12\ \ 16\ \ 14 \\
i &= \ \ 57\ \ 35\ \ 44
\end{aligned}\right\}\ 1890.0 \\
\log q &= 9.437828 \qquad q = 0.2745
\end{aligned}
$$

It is passing south rapidly, so that it will no longer be visible in this latitude. We have no ephemeris extending beyond Jan. 31. H. C. W.

Orbit of Comet g 1889 (*Borrelly, Dec. 12*). From my own observations of Dec. 17, 21, and 23, I have computed the following elements of Borrelly's new comet referred to apparent equinox:

$$
\begin{aligned}
T &= 1890, \text{Jan. } 24.9162 \text{ Gr. M. T.} \\
\pi &= 207^\circ \ 5' \ 13'' \\
\Omega &= \ \ 5 \ \ 24 \ \ 9 \\
i &= \ 55 \ \ 59 \ \ 44 \\
\log q &= 9.41694 \qquad q = 0.26118
\end{aligned}
$$

O. C. WENDELL.

Harvard College Observatory, 1890, Jan. 6.

NEWS AND NOTES.

There are only the names of a few persons on our subscription lists from whom we have not received orders concerning renewals for 1890. We pre sume that such do not wish THE MESSENGER continued.

This number contains an unusual amount of mathematical matter, but we esteem it useful to the general reader as well as to the scholar. The habit should be formed of trying to read or do things that are mentally hard to do. Suppose one cannot fully and readily understand every point that a scholarly writer makes, that is no good reason why he should not try patiently to get something from such sources. The better way is to compel the mind to go deeper and higher every day by painstaking work.

We have not yet met with the degree of success in our illustrations which we hoped for four months ago, though very earnest efforts have been put forth constantly in this direction, with some gain, and promise of more in the future.

Two or three subscribers are inquiring concerning the purchase of sm al second hand telescopes. Any persons having such instruments for sale, in good condition, are requested to give us full information.

An interested European subscriber and correspondent to THE MESSENGER has recently made some very pertinent suggestions in regard to mathematical articles. He says: "I wish some more good mathematicians would apply themselves to astronomical problems. Now, that the satellite theory of Algol seems to be proved, the variations of its period become important, as well as the much greater variations of a star of the same class in Cygnus. It would be easy to name other problems which it would be of much use to solve."

Professor H. A. Peck of the Observatory of Syracuse University, Syracuse, N. Y., has just completed a set of tables for the prediction of occultations for latitude $+ 43^\circ 3'$.

George A. Hill, Naval Observatory, Washington, D. C., has recently furnished THE MESSENGER very helpful suggestions and useful comet notes.

The Halsted Observatory of the College of New Jersey, Professor C. A. Young, Director, has just been fitted with a new electrical plant for managing the dome. A four-horse power C. & C. motor is connected with the old machinery formerly driven by a four horse power Otto gas engine, and a Julien Storage battery of thirty-two cells supplies the current to work the motor. With this arrangement the observer himself can easily manage the apparatus alone. Formerly it was necessary to call on a machinist to start the engine, which was often a difficult operation, requiring a great expenditure of muscular energy, and a perfect knowledge of all the tricks and whims of the machine. When the engine was once started it was usually left to run during the whole time of observation, which, of course, involved a great waste of power, and was objectionable on account of the tremor, noise and heat. The battery is charged at odd times as it becomes necessary either by a small dynamo (in the Observatory) which is driven by the gas engine, or by a current sent down from the dynamo house at the School of Science building, 1000 feet away.

Astronomy in the year 1886. The account of the progress of Astronomy in the year 1886 was prepared by William C. Winlock for the Smithsonian report for the years 1886-87, but the publication of the same was delayed until late last year, on account of the lack of appropriations for this class of work, if we are rightly informed. This makes the appearance and notice of this useful pamphlet late for our readers, but we suppose it can not be helped in this instance, on the part of those in the charge of its preparation. It is to be hoped that these reports subsequently will appear more promptly for the good of the science they are intended to serve.

The method and arrangement for the Review of Astronomy for 1886 is essentially the same as the companion numbers from 1879 to 1884, the object being to prepare a series of notes from all the various branches of Astronomy, that may be of service to those who have not access to a large astronomical library. The feature of astronomical bibliography is deservedly made prominent, for that is certainly useful to the professional astronomer as a reference list of technical papers.

The article on the comets for the year is a suggestive one in regard to complete and ready reference by systematic designation. A grouping of the different names that individual comets take, as a side head, in different type, is an excellent idea. Some such way of referring to comets after the year of their appearance has passed, would always be definite, avoid errors and save confusion. This series of astronomical notes is very well prepared as in fact, everything of the kind is that Mr. Winlock undertakes.

Quartz Fibre. This beautiful invention of Mr. Boys supplies exactly what is wanted for micrometer wires, or, in fact, wherever a strong, regular and delicate thread is wanted. Almost anyone with a little patience and practice can make it, and the making is a very interesting experiment, well worth the doing of itself. These little threads can be had of any size, —one ten-thousandth of an inch diameter (if one cares to handle them as small), are perfectly round, straight and polished, which can be said of no other wire. A position micrometer recently fitted with wires of this material performs admirably. C. C. HUTCHINS.

BOWDOIN COLLEGE, Jan. 1, 1890.

Delta and Mu Centauri Show F Hydrogen Line Bright. An examination by Mrs. M. Fleming of the photographs taken by Mr. Bailey in Peru has led to the discovery that the F line due to hydrogen is bright in δ and μ Centauri. Additional photographs with shorter exposure will be required to decide whether the other hydrogen lines are also bright since the spectra so far obtained are too intense. This makes the total number of objects of this class as yet discovered seven, γ Cassiopeiæ, φ Persei, π Aquarii, P Cygni, 28 Tauri (Pleione), δ Centauri and μ Centauri. The stars having bright lines in their spectra discovered by Rayet and the variable stars of long period belong to different classes.

New Artificial Horizon Apparatus. In the New York *Evening Post* of Dec. 18, 1889, the reviewer of "Hints to Travelers," a manual for explorers, published by the Royal Geographical Society of London, calls attention to the fact that the glass shades ordinarily used in connection with the artificial horizon in sextant work, may be dispensed with, a light wooden frame-work covered with gauze being substituted therefor.

Apropos of this subject it may be interesting to call attention to a comparatively new form of artificial horizon, which, as regards portability and ease of handling, presents marked advantage over the mercurial horizon. This new device consists of two dishes of glass, mounted with a space between them in a light brass frame which is supported by three leveling screws. The image of the object observed upon is, of course, reflected from the plane surface of the upper dish. The space between the dishes is nearly filled with ether, leaving a bubble which, by means of the leveling screws, enables the reflecting surface to be placed perpendicular to the direction of gravity. Sextant observers will do well to give this new horizon apparatus a trial. JOHN TATLOCK, JR.

Bibliographie Generale de l'Astronomie, by J. C. Houzeau, Director of the Royal Observatory at Brussels and E. A. Lancaster, Librarian, is a work of very great labor and value. The second volume, containing 2225 pages, was published in 1882, and presents the following leading topics in separate sections: History and Study of Astronomy; Biographies of Astronomers; Spherical Astronomy; Theoretical Astronomy; Celestial Mechanics; Physical Astronomy; Practical Astronomy; Monographs on the Principal Bodies of the Solar System; and Stellar Astronomy. Each topic is arranged on some plan that makes reference to any matter belonging to it very easy and natural, the different kinds of type on the same page serving as an index. The amount of useful information collected in this volume is an agreeable surprise. The first part of the first volume by the same authors, and published by F. Hayez, printer for the Royal Academy of Belgium, appeared in 1887 and is a neat volume of 858 pages. The entire volume is devoted to printed works and manuscripts on astronomical themes. The first half of this part presents a series of articles on the intellectual development of different phases of the science of astronomy. The remaining topics for this part are two, viz: (1) Historical Works, (2) Astrology, with subjects in chronological order. Some idea of the generality and completeness of research will be conveyed to the reader, if we

say that under these two heads are found 3915 subjects each having a few points of interest for further guidance in study. The second part of this first volume was published in October last and was received only a few weeks ago. Its frontispiece is a beautiful plate engraving of J. C. Houzeau, and the introductory article is a biographical sketch of this distinguished and scholarly astronomer. The body of this part is divided into four sections treating of (1) Particular Biographies, (2) Didactic and General Works on Astronomy; (3) Spherical Astronomy, (4) Theoretical Astronomy. This work, as a whole, is a most useful part of an astronomical library, and will be welcomed by American astronomers especially those who read the French.

Photographic Notes. Reports from the eclipse expeditions are as yet meagre. The United States government expedition made large preparations for its photographic work, Mr. Carbutt and Mr. Wright being the photographers of the party. Professor Holden writes of their outfit: "They are provided with a photoheliograph, giving an image of the sun four inches in diameter. With this the partial phases will be photographed on orthochromatic plates (No. 16) and the total phase on orthochromatic plates (No 27). A large mirror belonging to Professor Langley, an equatorial belonging to Harvard College Observatory, and twenty cameras are also provided for photography." Of the results we hear that all instruments worked perfectly; seventy photographs were secured before totality; clouds interfered with the work during the period of totality; after totality a number of pictures were secured. Twenty-two-inch plates were used, upon each of these ten exposures could be made. Some of this party worked far out at sea on the steamer Pensacola, while others were on the Afrien mainland near the mouth of the Congo.

The *Monthly Notices* of the Royal Astronomical Society for November, makes the following statement in regard to the English eclipse expedition. "The objects of the photographic outfit of the eclipse expedition of the Royal Astronomical Society are threefold:

1. To detect any possible changes in the corona during the two hours and a half that elapse between totality at the respective stations.
2. To photograph the coronal extension as far as possible.
3. To determine the photometric intensity of the corona."

A diagram giving the mean daily area of sun-spots for each degree of solar latitude has been prepared from photographs of the sun at the Royal Observatory, Greenwich, for the years 1874-1888. "The diagram shows in a marked manner the gradual decline in the distance from the equator of sun-spots as the minimum is approached, and the sudden appearance of spots in high latitudes after the minimum is passed, and a new cycle commenced."

Continued experiment with eikonogen is proving its exceptional value as a developer. J. B. Brown of the U. S. Army, makes the following statements as the result of "assiduous experimenting." "I give the combination I am now using, and which gives by far the best general results.

No. 1—Sulphite soda, 240 grains; water pure, 16 ounces; dissolve and filter, then add eikonogen, 120 grains.

No. 2—Carbonate of potash, 20 ounces (Troy); water, 12 fluid ounces. Use three ounces of No. 1 with one part No. 2.

The result will be a clear, unstained negative, with every detail in shadows and lights clearly brought out, and the exposure may be less than one half that proper for a hydrochinon developer."

C. H. Poor, after experimenting on one hundred negatives of the same landscape, writes: "The conclusion I have come to is, that for shutter work eikonogen is without a peer; but for time exposures more snap and more contrast can be got from either pyro or hydro, with the advantage largely in favor of the latter."

The Solar Corona is the name of a recent paper prepared by Professor Frank H. Bigelow, and published by the Smithsonian Institution at Washington, D. C. The mode of attacking the puzzling problem of the corona is by the principles of spherical harmonics, and the author makes an interesting study of three points in the structure of the corona, viz.: (1) Polar rays nearly vertical to the coronal poles or axis of reference for the symmetrical figure, but inclining more from this axis than a radius vector to any point, as the vectoral angle increases; (2) Four wings disposed upon two axes, each inclined at an angle of 40° from the vertical; and (3) Extensive equatorial wings seen more distinctly at periods of solar quiescence. The supposition that supports the theory advanced is, that the rays observed are lines of force discharging coronal matter from the body of the sun, and that the phenomenon seen is similar to that of free electricity. The mathematical part of the paper presents both the harmonic theory and the geometrical. The former is drawn from well known treatises on harmonics by Todhunter, Thompson and Tait and others; but the more important feature is the application of this theory to the explanation of the corona. The author thinks that the straight polar rays of high tension carry the lightest substances, as hydrogen, meteoric matter, *debris* of comets, and other coronal material, away from the sun, and they become soon invisible by dispersion; that the strong quadrilateral rays which form appendages conspicuously seen at periods of great solar activity rapidly diminish, and at the distance of one solar radius have a small potential comparatively. The explanation of the long equatorial wings, with absence of well marked quadrilaterals, at periods of minimum activity, is due to the closing of the lines of force about the equator.

For detailed study the author applies his theory to the drawing of the corona by Professor Holden as observed during the total eclipse of Jan. 1, 1889; also to the photographs of same eclipse made by Professor Pickering. The results, to say the least, are suggestive, and possibly offer a clue to the explanation of the solar corona that is worthy of further critical study.

November Meteors. The night of November 16th last was very clear. A deep, dark, but brilliant sky presented itself and every object stood out wonderfully prominent. Twenty eight meteors were counted in one hour (about 9 to 10 P. M.) Two were of a decidedly bluish color. Nearly all proceeded out of the usual locality of the heavens already famous as a radiant point. My observation did not cover the previous evening, and only for about the hour of the evening mentioned. E. J. BROOKINGS.

Washington, D. C., Dec. 1889.

Total Eclipse of Dec. 22 at Cayenne, South America. Mr. Charles H. Rockwell, who was in company with the Lick observing party at Cayenne, has very kindly sent us details of observations of the late total solar eclipse. Though given in a private letter we are sure our readers will enjoy most what he says in his own words as follows:

"It is a week to-day since the eclipse was seen here. Perhaps your regular correspondent at this point has already reported the success of our observations so that the notes of an occasional contributor merely repeat old news. The only party who did any work here was composed of Messrs. Burnham and Schaeberle, from Lick Observatory, and your humble servant. I did not bring any instruments, coming to see the country, and to put in the time on the way to California. There is only one regular communication a month between Cayenne and the world at large. I left Martinique on this regular steamer, and was joined at Trinidad by Messrs. Burnham and Schaeberle, so that we arrived here in company on 30th November. As we approached our destination, the information which we received was not calculated to raise our spirits or to strengthen our hopes. We have struck the rainy season for this section, and rain here means business—no foolishness. However we went to work, and were all ready for the event some days in advance. It rained steadily all night before the eclipse. We turned out before daylight; the rain had stopped, but the morning was so dark and cloudy as to give no hint which was east or which was west. In fact, we did not once see the sun until more than half an hour after first contact. Then came a short shower and a break in the clouds showed the moon covering two thirds of the sun's disc. Of course the atmosphere was charged with moisture—94 per cent is the normal condition of things here—but there was no cloud between us and the moon. All our work was in the line of photography—nothing else was attempted. Mr. Burnham used a six-inch equatorial from the Lick Observatory with the aperture reduced to three inches. Mr. Schaeberle had a Dollinger photographic telescope also of six inches belonging to the Naval Observatory—full aperture. I helped to manipulate an eighteen-inch reflector belonging to Mr. Schaeberle which he fixed up in a most ingenious manner. Two pieces of joist, 3 × 4 inches, 12 feet long, were held a foot apart by slats and braces. This was the backbone of the tube. Six or eight barrel hoops were nailed to the joists—these were the ribs—and over these was a covering of black calico. A barrel was sawn in two, ten inches from the head end, and so as to give a tub in which the reflector disc was packed. The elevation and azimuth were determined in advance and a screw was turned, one revolution in ten seconds, so as to keep the focus on the photographic plate. As it was wholly a volunteer move on the part of Mr. Schaeberle to bring this glass along, it seemed eminently proper that the volunteer observer should use it. If any results were obtained, well and good; if not, then no program was interfered with and no harm was done. We each exposed four plates and the whole twelve have turned out good. On some of them the curved rays of the corona are beautifully shown. Father Perry and his party were stationed on the Isle de Salut, about twenty-five miles off shore from here; they, too, had fair weather. A French amateur observer, Count de Baueve, was also on the island. He carried out instructions given him by M. Janssen as to the details of his work. He has not yet developed his plates. The governor of this colony, M. Gerville Roach, has treated us in the kindest manner possible, doing all in his power to aid us. The living here is poor enough, just sufficient to keep soul and body together. Messrs. Burnham and Schaeberle are in good health. I have been only tolerably well since coming ashore. We shall be glad to get away by the steamer of 3d January.

Cayenne, Dec. 29, 1889.

BOOK NOTICES.

THE ELEMENTS OF ASTRONOMY. A Text Book for Use in High Schools and Academies. By Charles A. Young, Ph. D., LL. D., Professor of Astronomy in the College of New Jersey. Boston, U. S. A., and London: Messrs. Ginn & Co., publishers, 1890; pp. 430. Supplement Uranography, pp. 42, with 4 double-page maps of the constellations.

Teachers or students who may be somewhat acquainted with the author's General Astronomy for Colleges and Scientific schools may have the impression that this new book is a mere abridgement of the other and large one. A careful examination of it, however, will correct any such erroneous notion, and will show that everything has been worked over and adapted to the needs of a High School course, as observed in the best schools of this class. The standard for the pupil is placed high, as probably many teachers will say as the new work is examined, and some may hastily conclude that it is too difficult for the place it is intended to fill, but we do not believe that to be a fair estimate of the book at all, nor a wise forecasting of what it will do if tried in the class-room in the hands of a live teacher. For one, we are glad to find one more author added to the short list of text-book writers who are able to make a book that has the power in it to stimulate thought, and to bring pupils out of habits of narrow and one-sided ways of looking at things, and to arouse in them a desire for further acquisition. At danger points the teacher must step in and regulate the aim of truth, to be sure, in all cases, that it do not overshoot the range of the pupil's intelligence. Another feature impresses us strongly. In an elementary text book some statements must be incomplete, but it is important that all should be correct and accurate as far as they go. Incompleteness of statement does not necessarily involve that which is false, although it sometimes happens that the two ideas are found in company in elementary studies. The experience and skill of the teacher are likely to divorce these natural enemies when he writes a text book for young minds which he has learned to know as others cannot appreciate them. The general order of the matter of this book is about the same as that of author's General Astronomy, and the arrangement of the topics in chapters is as follows:

1. Fundamental Notions and Definitions. 2. Fundamental Problems of Practical Astronomy. 3. The Earth. 4. The Orbital Motion of the Earth and its Consequences. 5. The Moon. 6. The Sun. 7. Eclipses. 8. Celestial Mechanics. 9. Planets in General. 10. The Individual Planets. 11. Comets and Meteors. 12 and 13. The Stars. Then follow three chapters giving supplementary matter to articles in the text, methods for determining the solar parallax, a description of astronomical instruments, tables of useful astronomical data, questions for review, and a general index.

We have before spoken in detail of the subject matter of the Author's General Astronomy and hence it is not necessary now to particularize in our review in the same way. For those who have seen neither book, it may be proper to say, that, in our judgment, both are books of very remarkable worth for the places they are respectively designed to fill. A final word may be added respecting the "suggestive questions" for use in reviews and Uranography. We want to call the attention of teachers to the free and frequent use of these queries and similar ones which they will suggest. Those who have not tried such exercises we believe, are not at all aware, what a rapid, lively run of such questions will do a student and turn the knowledge of the text-book to familiar, practical uses. Much in the same general way might be said of practice in the elementary study of Uranography. This text-book will help the live teacher and the willing student in such ways as these in addition to the ordinary modes of study.

ASTRONOMY, NEW AND OLD. By Rev. Martin S. Brennan, A. M., Rector of the Church of St. Thomas of Aquin, St. Louis, Mo., Author of "Electricity and Its Discoveries," and "What Catholics Have Done for Science." New York: Catholic Publication Society Co., 9 Barclay Street. London: Burns & Oates. Pp. 268.

The author suggests in the preface of this new book that its object is "to give an epitome of the vast science of astronomy in the simplest and most concise manner possible, and that he aims at the utmost fairness throughout the work and that particular care is exercised in this respect, in the treatment of the history and the different hypotheses of the science.

The title, "Astronomy, New and Old," is an appropriate one; for the old astronomy is the most perfect of the sciences, reaching back through the times of the great Hipparchus to the dawn of tradition, while the new astronomy is of recent birth, scarcely yet twenty years old, but by its wonderful progress, a new field of brilliant and fascinating research has been opened that the author well names by the broad terms, the science of celestial physics.

This book contains sixteen chapters with the following titles, respectively: History; Division of Time and the Calendar; Spectroscope; Sun; Moon; Planets: Are the Planets Habitable?; Comets; Shooting Stars; Zodiacal light; Starry Heavens, including (1) Constellations, (2) Stars, (3) Star Clusters and Nebulæ; Celestial Photography; Celestial Measurements; and Mechanism of the World.

The chapter on the History of Astronomy, consisting of 18 pages and covering a period from the time of the Chaldeans to the present, is concise, well written, and, so far as we notice, accurate in statement. The second chapter treats of the division of time and calendar. This is the best and clearest *brief* statement of these interesting themes that we have noticed in any modern book on the elements of astronomy. At almost a single reading the student is in possession of the facts about the calendar that he can easily remember and readily apply. Accompanying the chapter on the spectroscope is a full page plate, in colors, showing the spectra of the sun and three stars arranged for comparative study, and the brief account of the growth of science by the aid of the spectroscope, with the names of discoverers and the dates of their discoveries side by side, is a very useful run of historical information in convenient form for reference. The chapters on the sun, moon, planets, stars, and others connected indirectly thereto, are based on late researches, and give, in the main, the prevailing opinions of scholars of authority in their respective lines of study. In an epitomized treatment of so large a theme, it is almost unavoidable that incomplete statements will here and there creep into the text. We notice one such. On page 109 the velocity of light is said to be 185,000 miles per second as determined by the eclipses of Jupiter's satellites. By other and later proofs the accepted value is 186,330 miles. We did not notice this additional value elsewhere given in the book.

The topics of celestial measurements and the mechanism of the world are a plain setting forth of facts, methods and theories. We enjoyed reading the author's remarks on the latter theme especially. After a very full verbal quotation of the La Place theory or hypothesis, it is reviewed in a fresh, fearless way that evinces a comprehension of difficulties and a Saxon grip in statement that we think does not lack in dignity or force to claim the attention of thinkers and theorists themselves.

The new cuts from this book are from recent photographs by Professor C. M. Charroppin, S. J., St. Louis Observatory, and the Solar Eclipse party of Professor Pritchett, of Washington University, St. Louis, at Norman, California, Jan. 1, 1889. Attention is called to the advertisement of this book elsewhere given.

Books Received.

An Elementary Treatise Upon the Method of Least Squares. By GEORGE C. COMSTOCK, Director of Washburn Observatory, Madison, Wis., Messrs. Ginn & Co., Publishers, Boston, Mass.

The Elements of Differential and Integral Calculus. By T. A. SMITH, Professor of Mathematics and Physics, Beloit College, Wis.